Towards global urban mapping by means of ESA SAR data

the SAR4Urban project

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Earth Observation Center (EOC)
German Remote Sensing Data Center (DFD)
Land Surface (LAX)

innovators
sarforurban

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Motivation

- More than half of the global human population is living in urban environments;
- Rapid urban growth brings several challenges, including meeting accelerated demand for basic services, infrastructure, and affordable housing (particularly for the nearly 1 billion people living in informal settlements).

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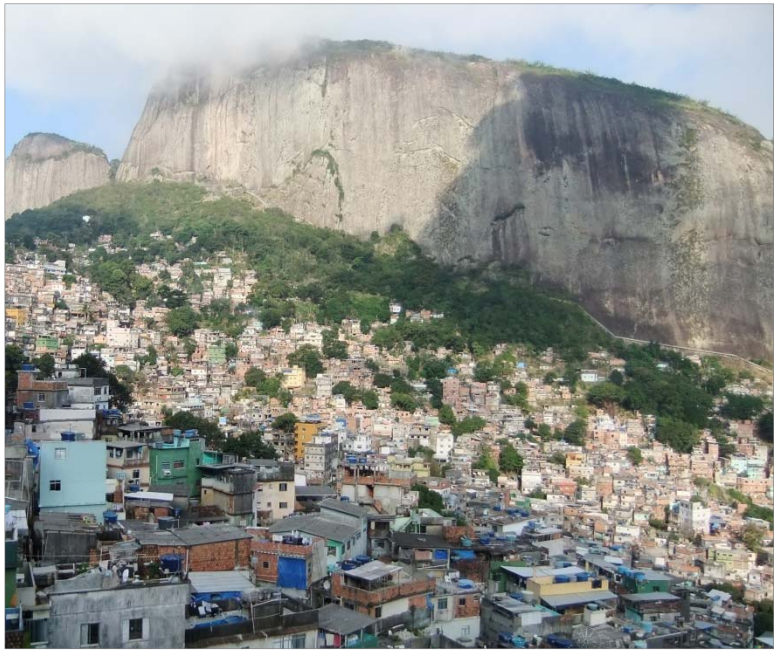
Motivation

- As cities develop, their exposure to climate and disaster risk increases;
- The most affected are the urban poor who tend to live e.g. along river banks and waterfronts in coastal areas on hillsides and slopes prone to landslides;

→ **An effective monitoring of urban sprawl is of paramount importance to understand the complexity of urban environments.**



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Motivation

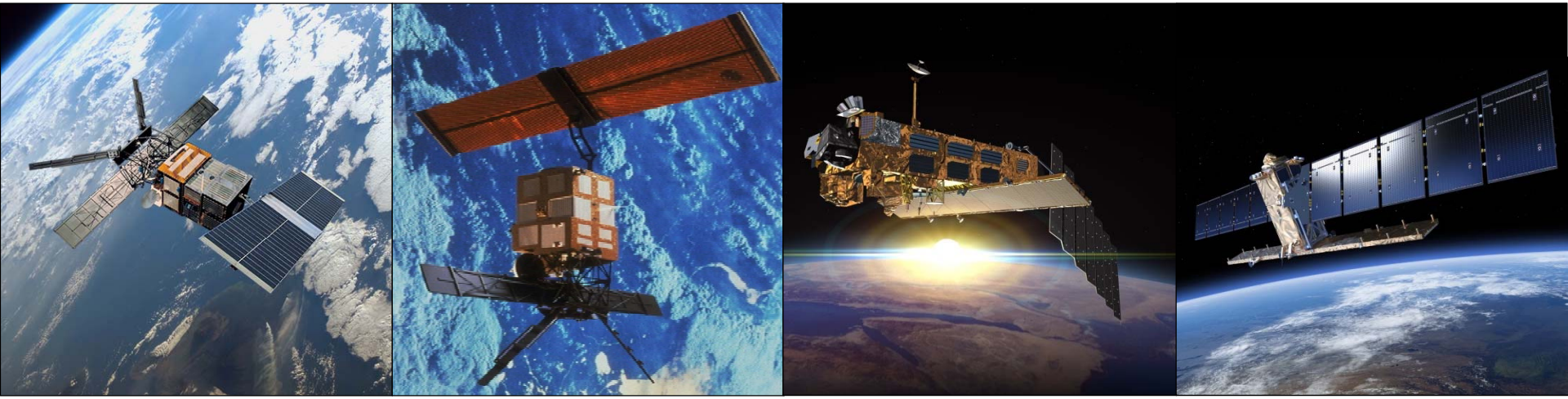
- At DLR we generated the **Global Urban Footprint** (GUF), a **mask of built-up areas** derived from TerraSAR-X and TanDEM-X data acquired between 2011 and 2013;

12m spatial resolution

www.dlr.de/guf

Motivation

- At DLR we generated the **Global Urban Footprint** (GUF), a **mask of built-up areas** derived from TerraSAR-X and TanDEM-X data acquired between 2011 and 2013;
- SAR data proved extremely effective for mapping urban areas.
- ESA SAR data are available:
  - from 1991 to 2012 (**ERS-1/2**, **ASAR**);
  - from 2014 onwards (**S1A**, **S1B**, S1C, S1D, …).



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SAR4Urban

- **Objective:** mapping past and current urbanization by means of ESA radar imagery.
- SAR4Urban is one of the 12 ESA DUE Innovators III projects;
- **Budget:** 200K;
- **Duration:** April 2015 – March 2017;
- **Users:**

THE WORLD BANK

The World Bank Group;

GEO

GEO Global Urban Observation and Information Task for Societal Benefits (GEO SB-04)

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Areas and Periods of Interest

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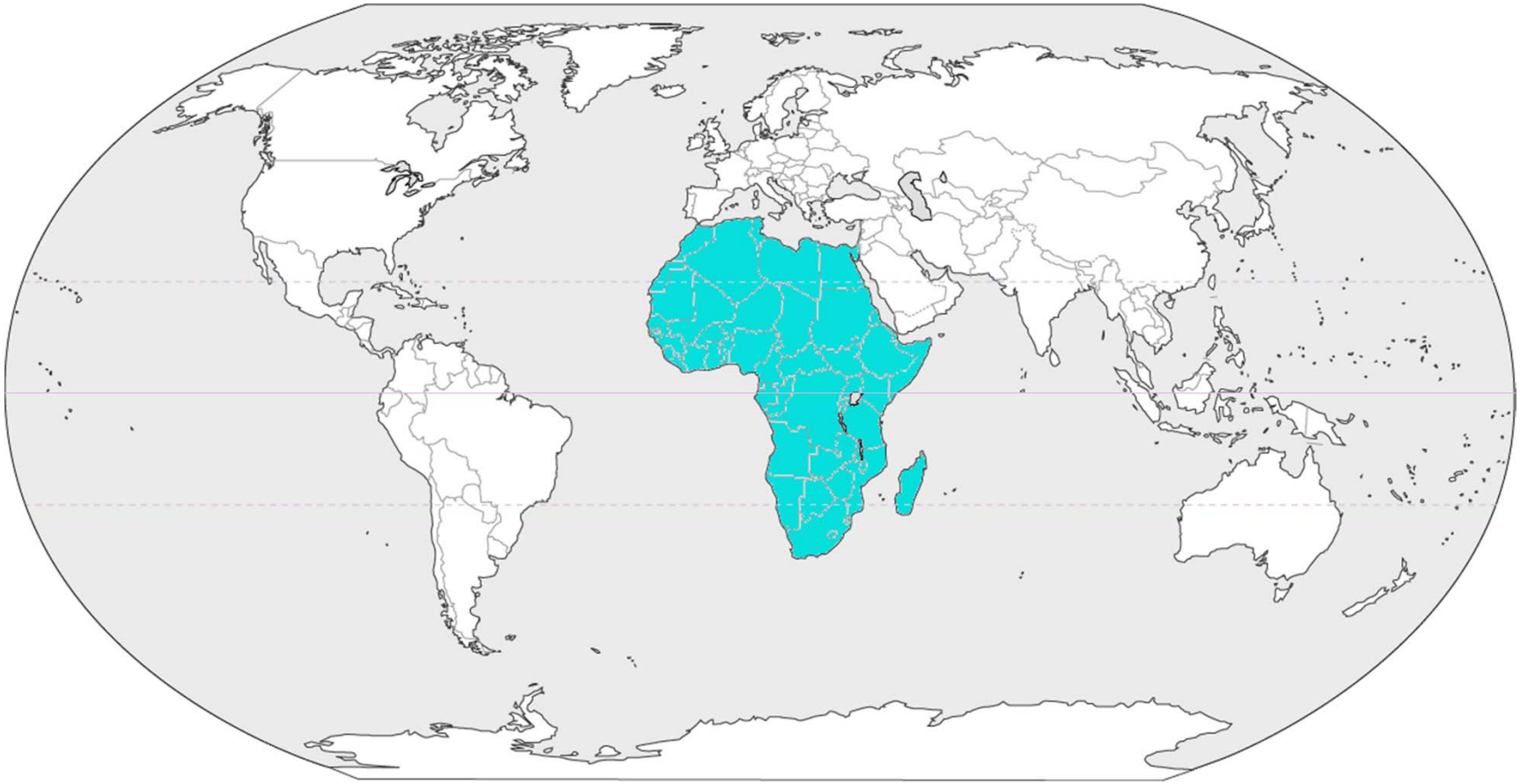
Areas and Periods of Interest

ASAR WSM 2002-2003

~75m spatial resolution



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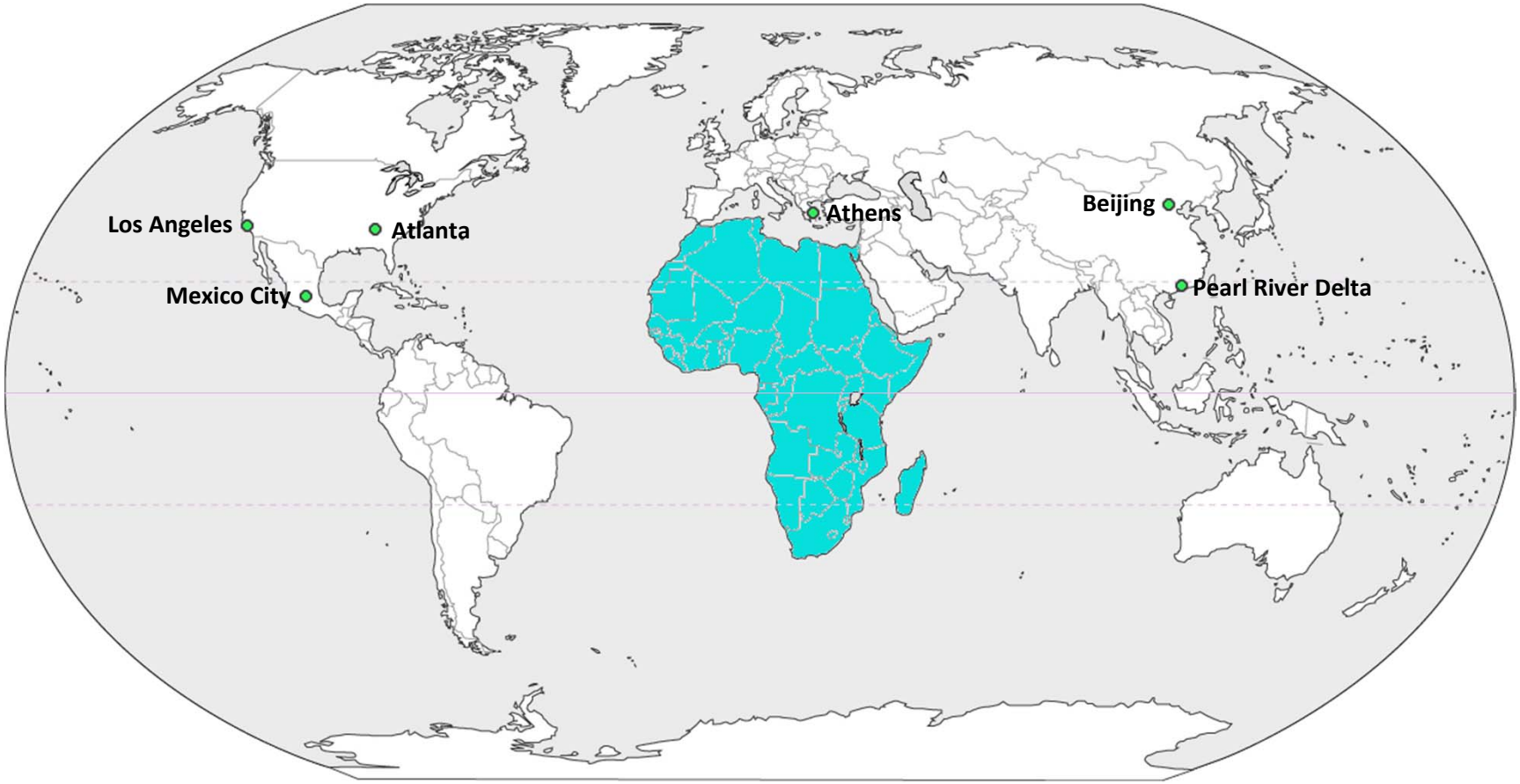
Areas and Periods of Interest

ASAR WSM 2002-2003
~75m spatial resolution

ERS-1/2 PRI & ASAR IMP 2002-2003
~15m spatial resolution



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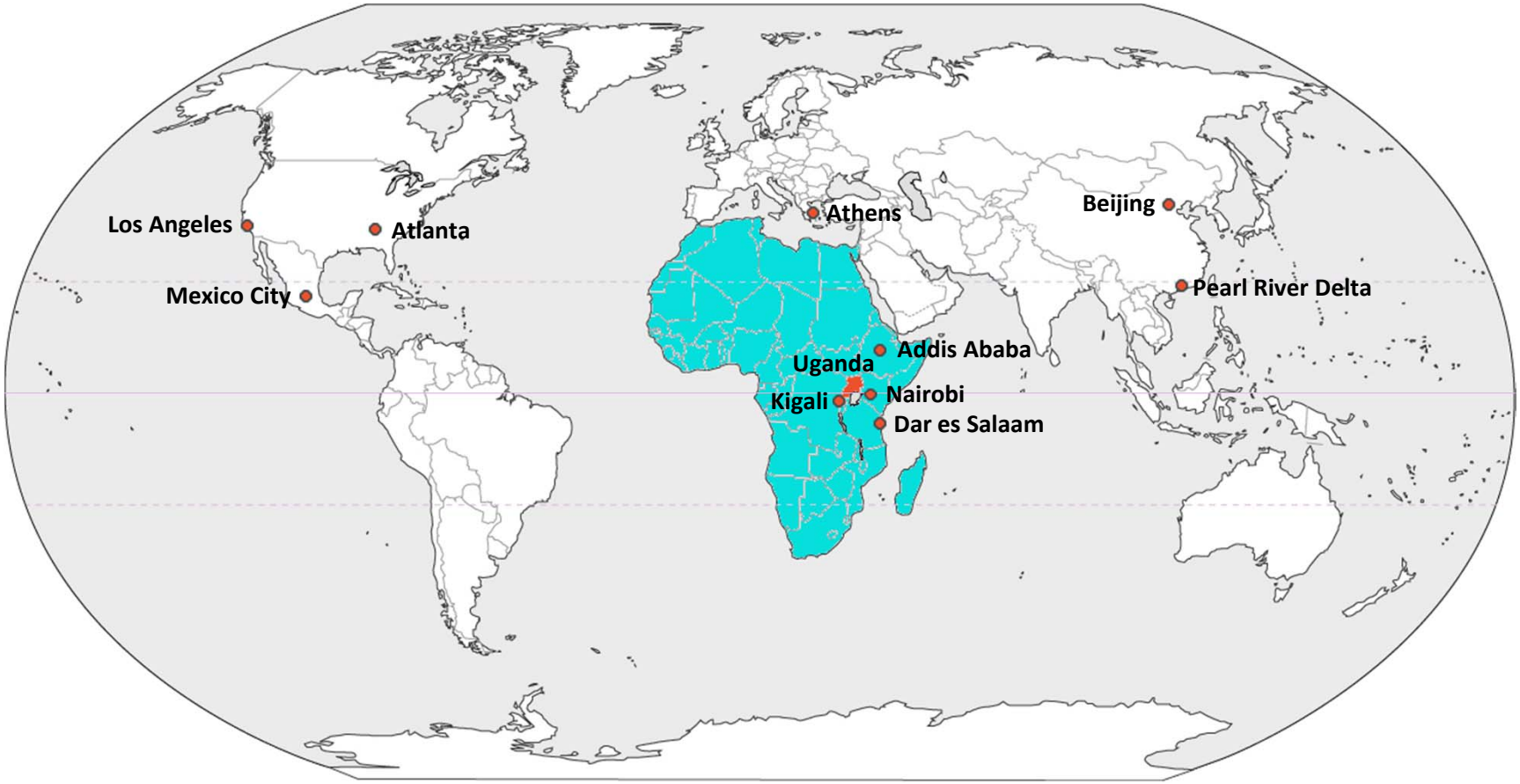
Areas and Periods of Interest

ASAR WSM 2002-2003
~75m spatial resolution

ERS-1/2 PRI & ASAR IMP 2002-2003
~15m spatial resolution

S1A IW GRDH 2014-2016
~10m spatial resolution



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Rationale

Given a series of multi-temporal SAR images for a given study area, the **temporal dynamics of urban settlements are sensibly different than those of all other non-urban classes**.

urban areas	→	always high backscattering
complex topography areas	→	high backscattering (can be masked by properly analyzing the DEM)
other non-urban areas	→	lower backscattering (high only under specific conditions)

Implemented Methodology

1. gathering all the multi-temporal images available over the region of interest in the selected time interval;

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Implemented Methodology

1. gathering all the multi-temporal images available over the region of interest in the selected time interval;

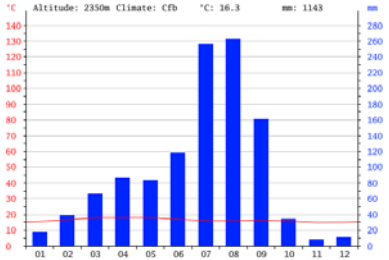
2. applying orbit correction, calibration, and terrain correction;

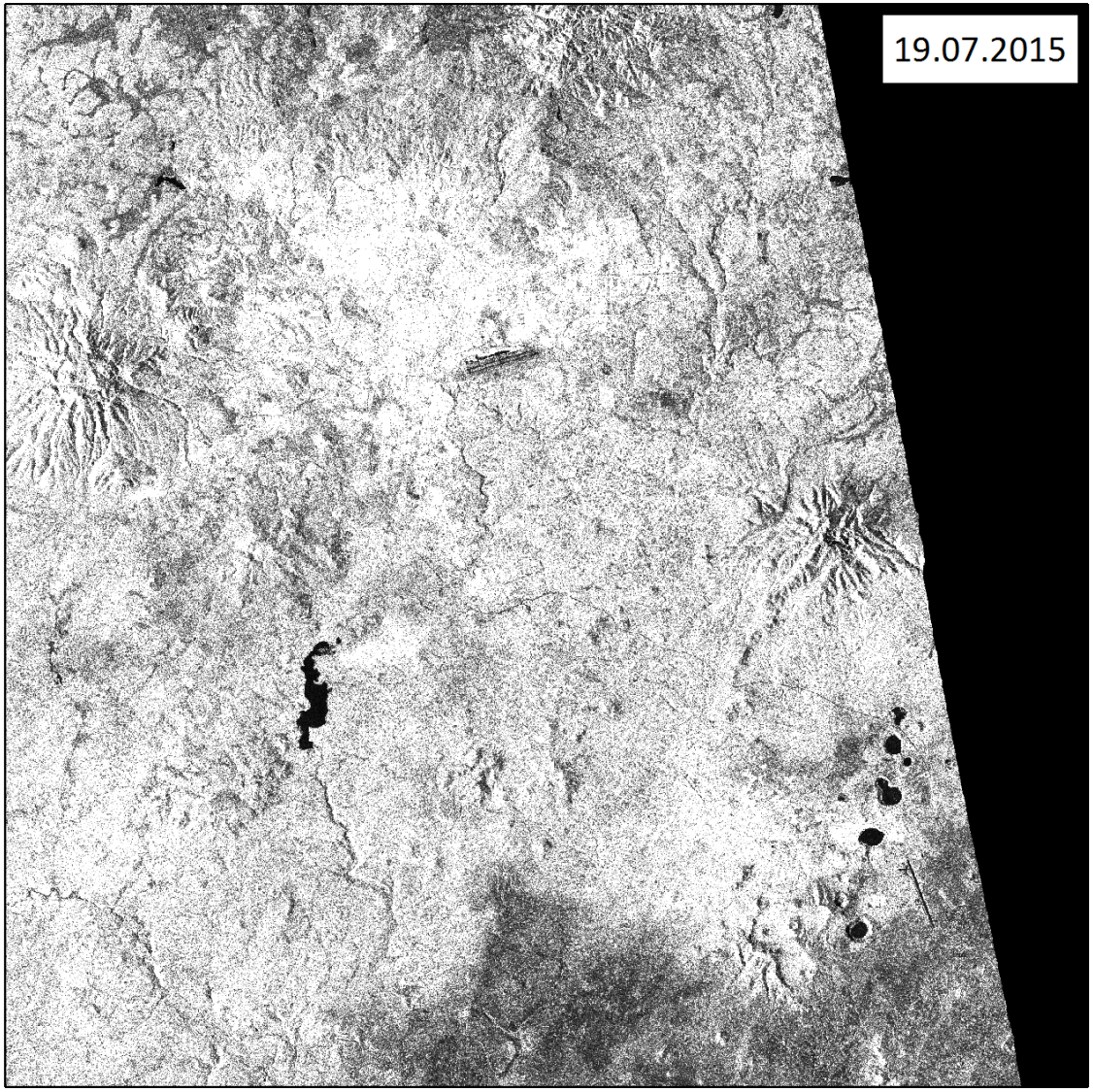
3. mask pixels associated with very low backscattering values;

Implemented Methodology

Addis Ababa

precipitation





S1A IW GRDH
VV
multitemporal
series
-
20 scenes
ascending pass
-
10m spatial
resolution

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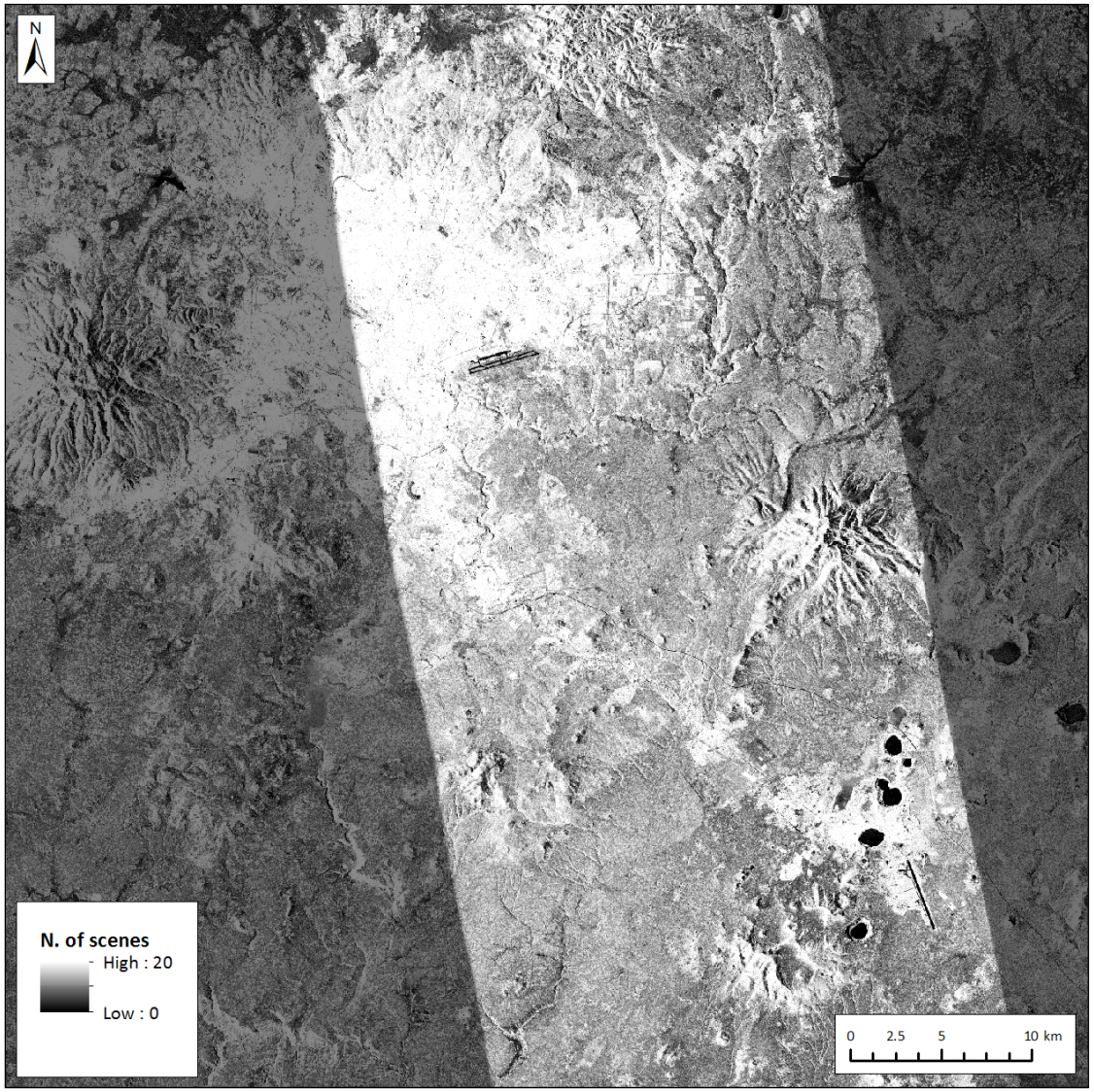
Implemented Methodology

Addis Ababa



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Implemented Methodology

1. gathering all the multi-temporal images available over the region of interest in the selected time interval;
2. applying orbit correction, calibration, and terrain correction;
3. mask pixels associated with very low backscattering values;
4. extracting for each pixel **key temporal statistics** (e.g., temporal median, mean, variance, standard deviation, mean slope, etc.);

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Implemented Methodology

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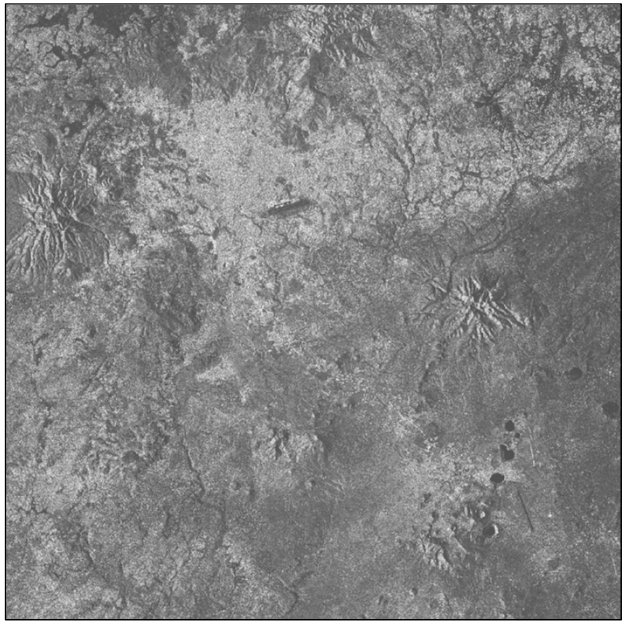
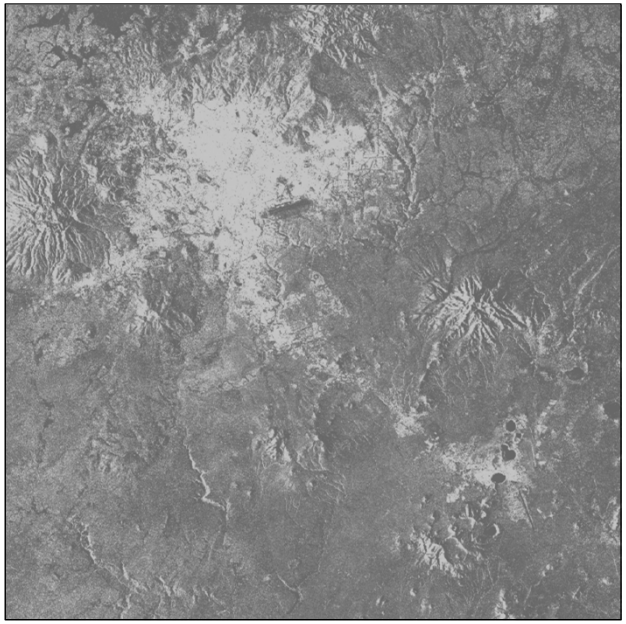
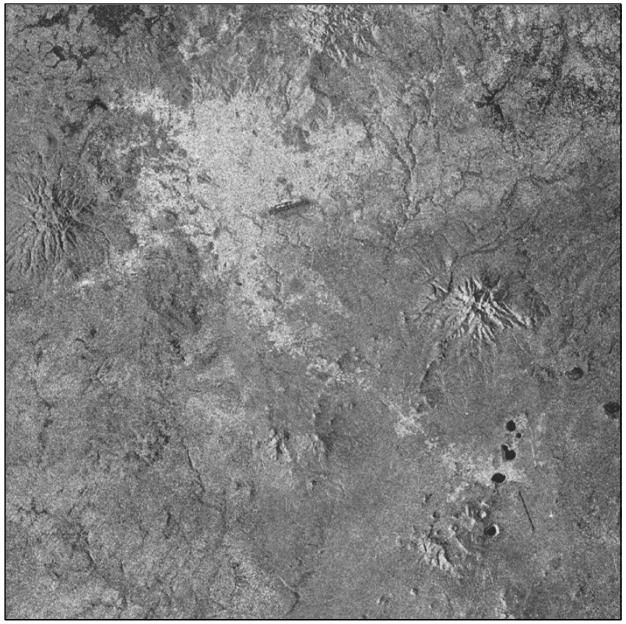
temporal σ^0 mean slope



temporal σ^0 mean



temporal σ^0 standard deviation



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Implemented Methodology

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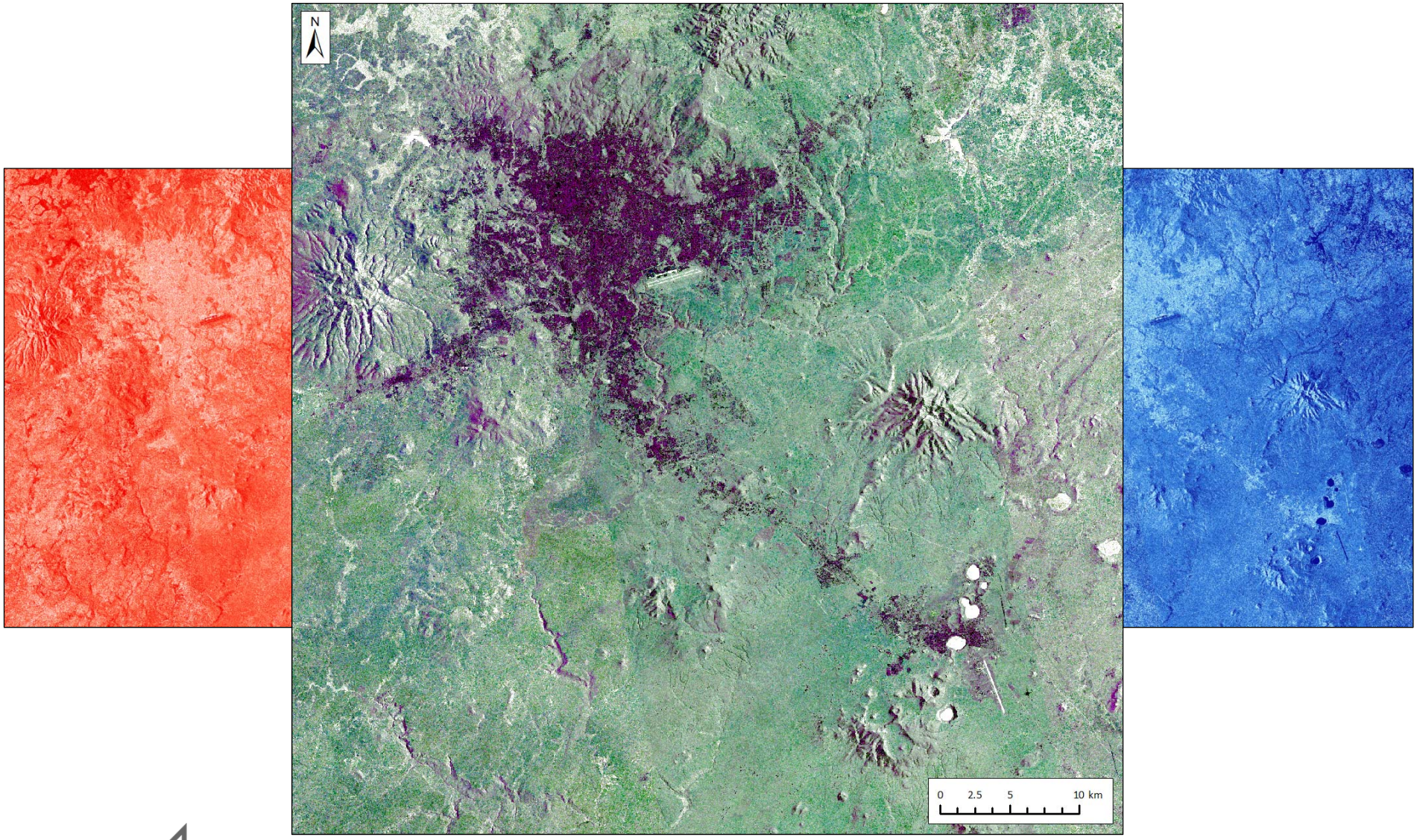

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1. gathering all the multi-temporal images available over the region of interest in the selected time interval;
2. applying orbit correction, calibration, and terrain correction;
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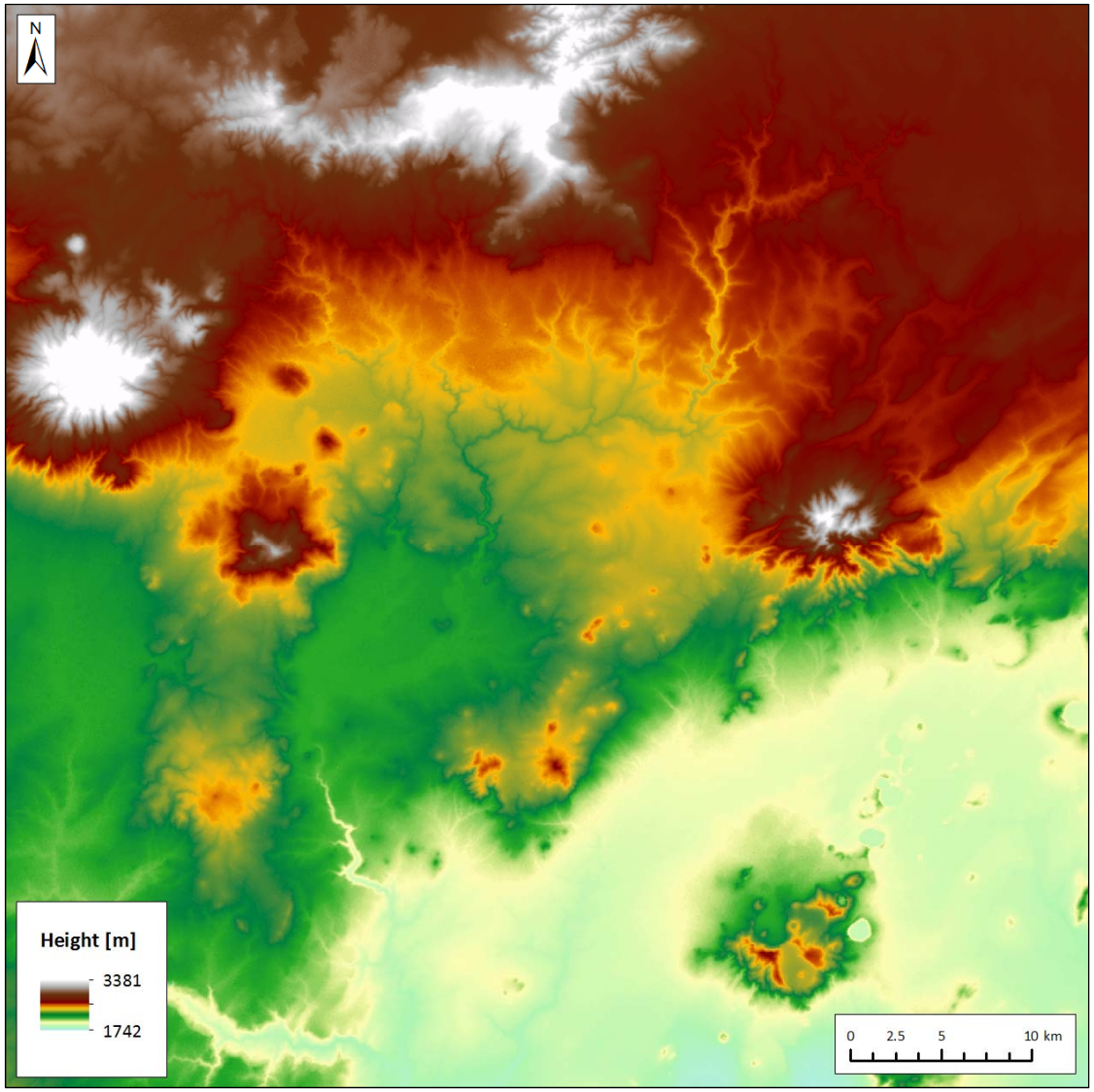
5. masking areas with complex topography;

Implemented Methodology

Addis Ababa



High-Resolution
SRTM 1 arcsec
(~30 m)

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Implemented Methodology

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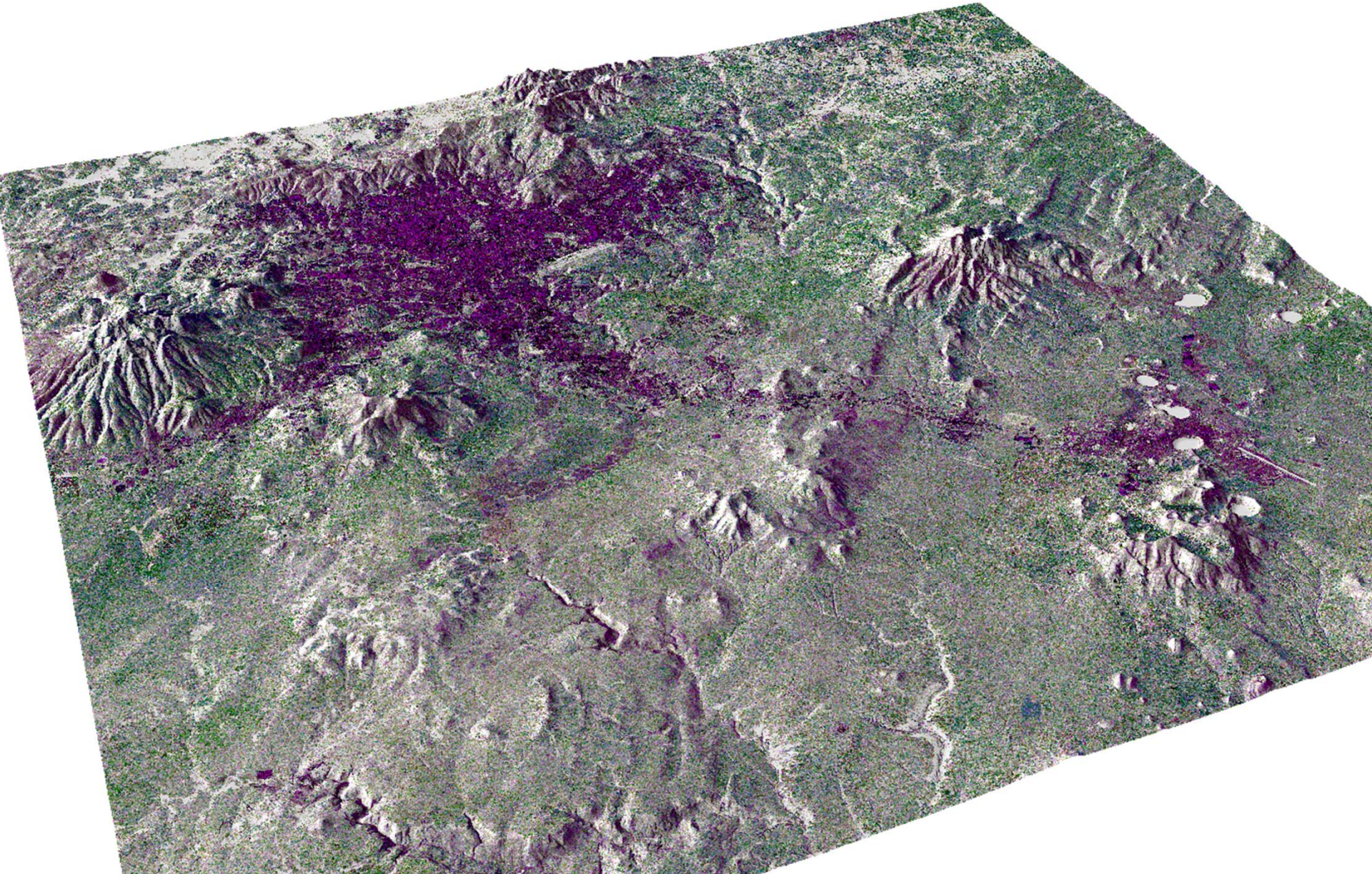

Implemented Methodology

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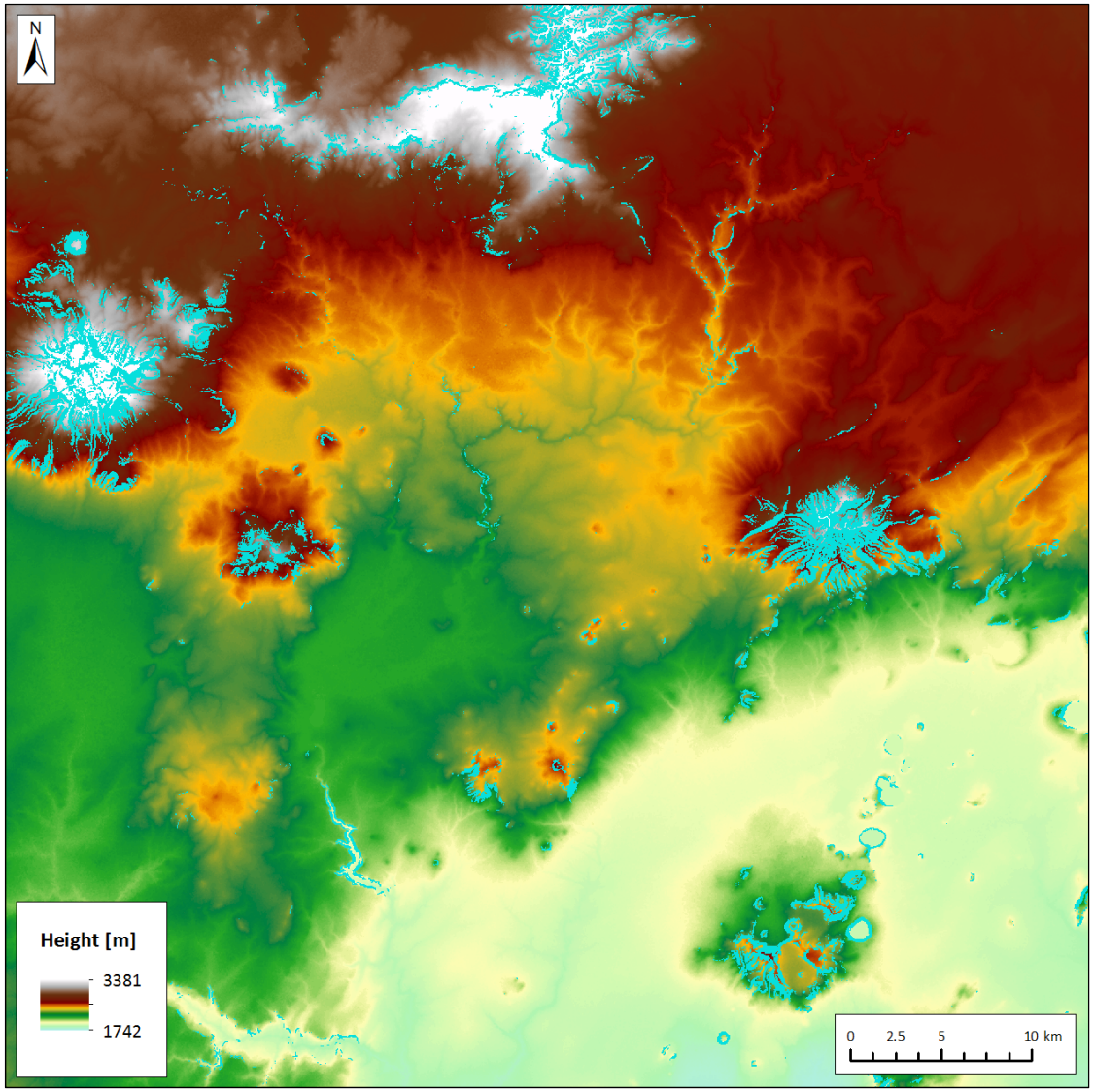

High-Resolution
SRTM 1 arcsec
(~30 m)
+
topography
mask

DLR

Implemented Methodology

1. gathering all the multi-temporal images available over the region of interest in the selected time interval;
2. applying orbit correction, calibration, and terrain correction;
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4. extracting for each pixel key temporal statistics (e.g., temporal median, mean, variance, standard deviation, mean slope, etc.);
5. masking areas with complex topography;
6. deriving **heterogeneity features** for the extracted temporal statistics (e.g., index of dispersion, **coefficient of variation**, etc.);

DLR

Implemented Methodology

1. gathering all the multi-temporal images available over the region of interest in the selected time interval;
2. applying orbit correction, calibration, and terrain correction;
3. mask pixels associated with very low backscattering values;
4. extracting for each pixel key temporal statistics (e.g., temporal median, mean, variance, standard deviation, mean slope, etc.);
5. masking areas with complex topography;
6. deriving heterogeneity features for the extracted temporal statistics (e.g., index of dispersion, coefficient of variation, etc.);
7. classifying using both temporal and heterogeneity features:
    - **Unsupervised Approach**;
    - **Supervised Approach** (for S1A data, training pixels extracted from GUF).

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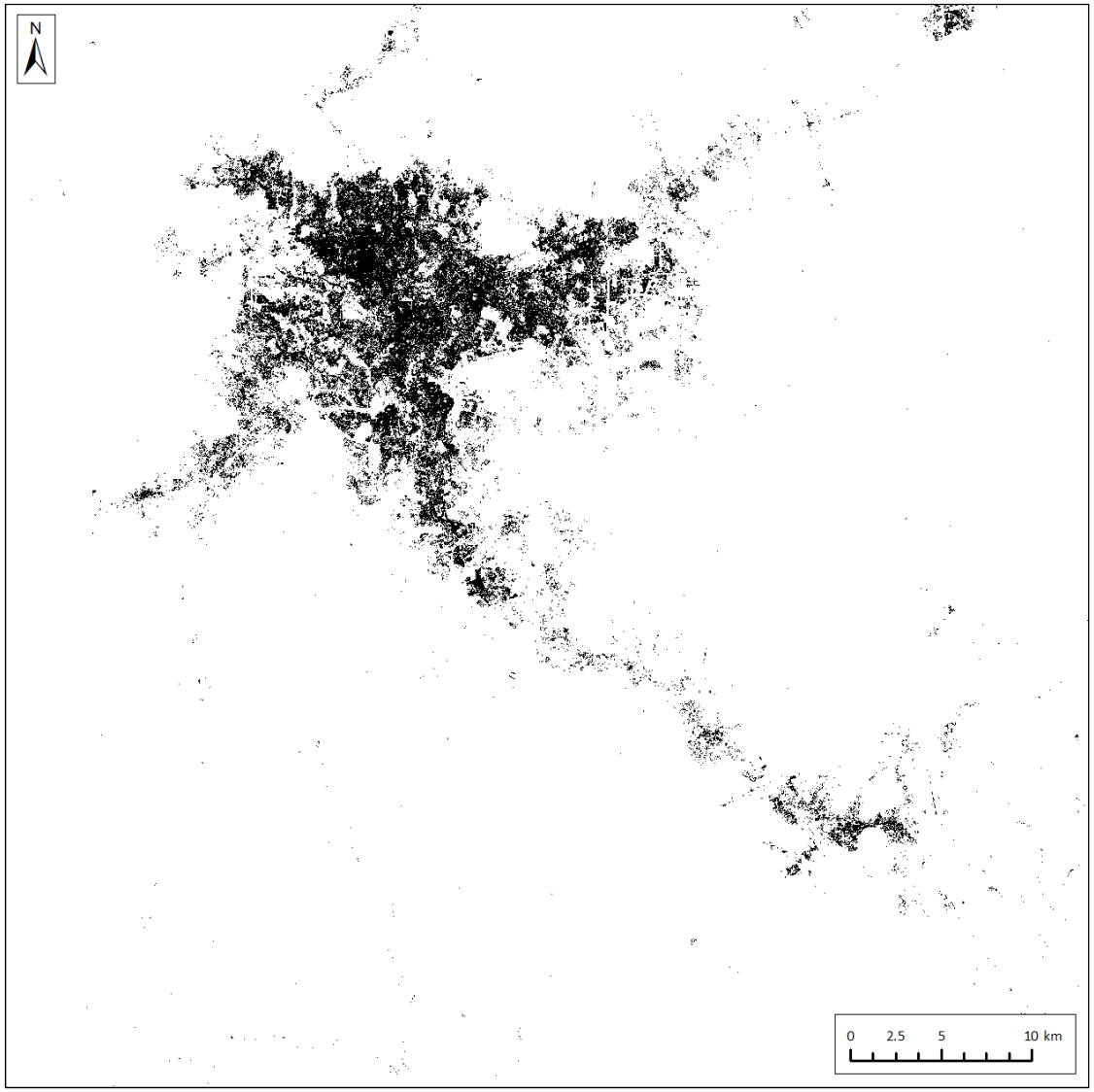
Implemented Methodology

Addis Ababa



DLR

First Results

The ASAR WSM pre-processing is supported by the **ESA RESEARCH & SERVICE SUPPORT (RSS)** team via **G-POD**.

In particular, the **entire global archive** is being processed and transferred to DLR via FTP:

2009 – 2012 → **completed**

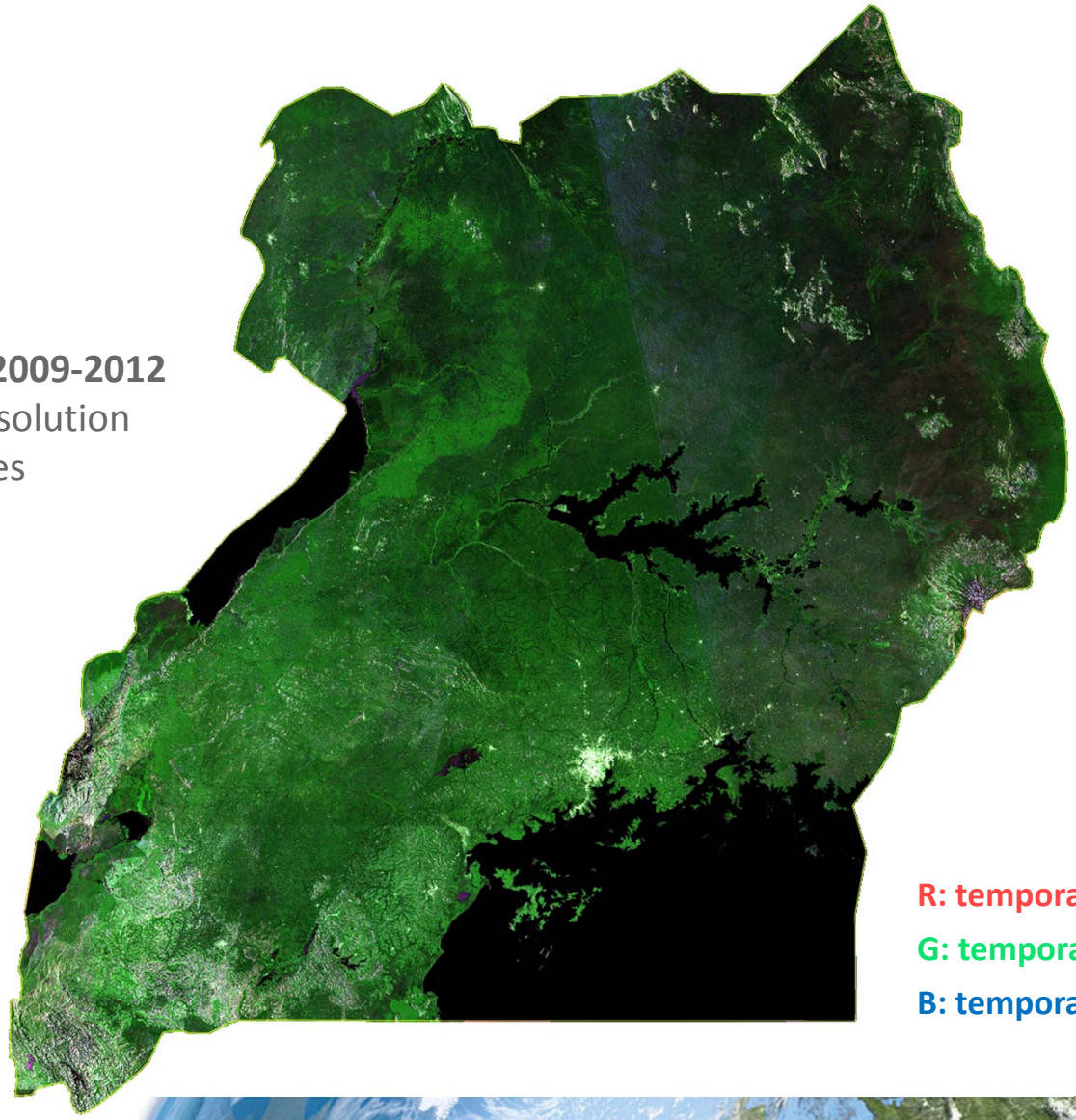
2002 – 2008 → **ongoing**

First tests are carried out mostly with 2009-2012 data.

First Results

Uganda

ASAR WSM HH 2009-2012
75m spatial resolution
71 scenes



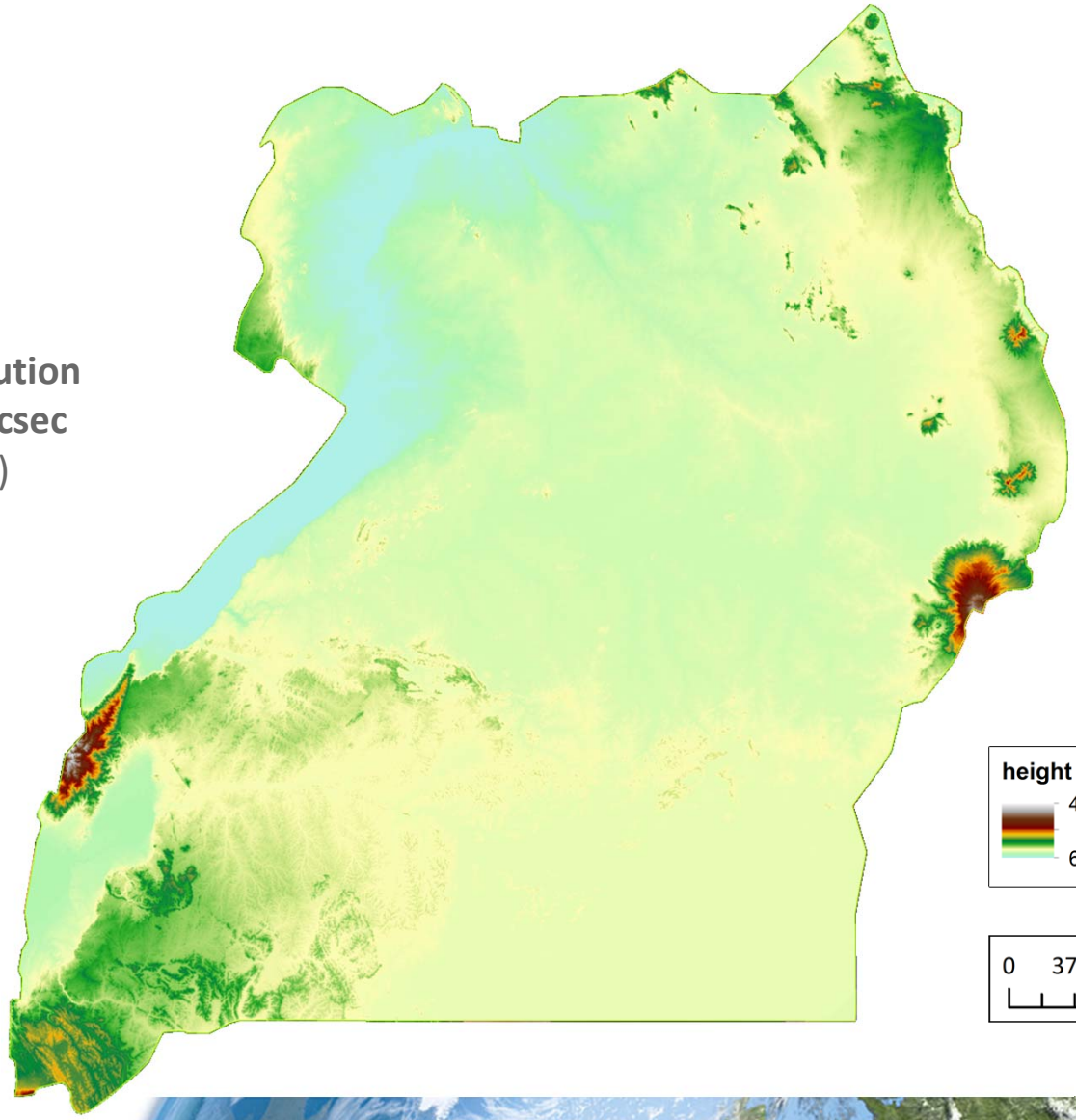
R: temporal σ^0 mean slope
G: temporal σ^0 mean
B: temporal σ^0 standard deviation

DLR

First Results

Uganda

High-Resolution
SRTM 1 arcsec
(~30 m)

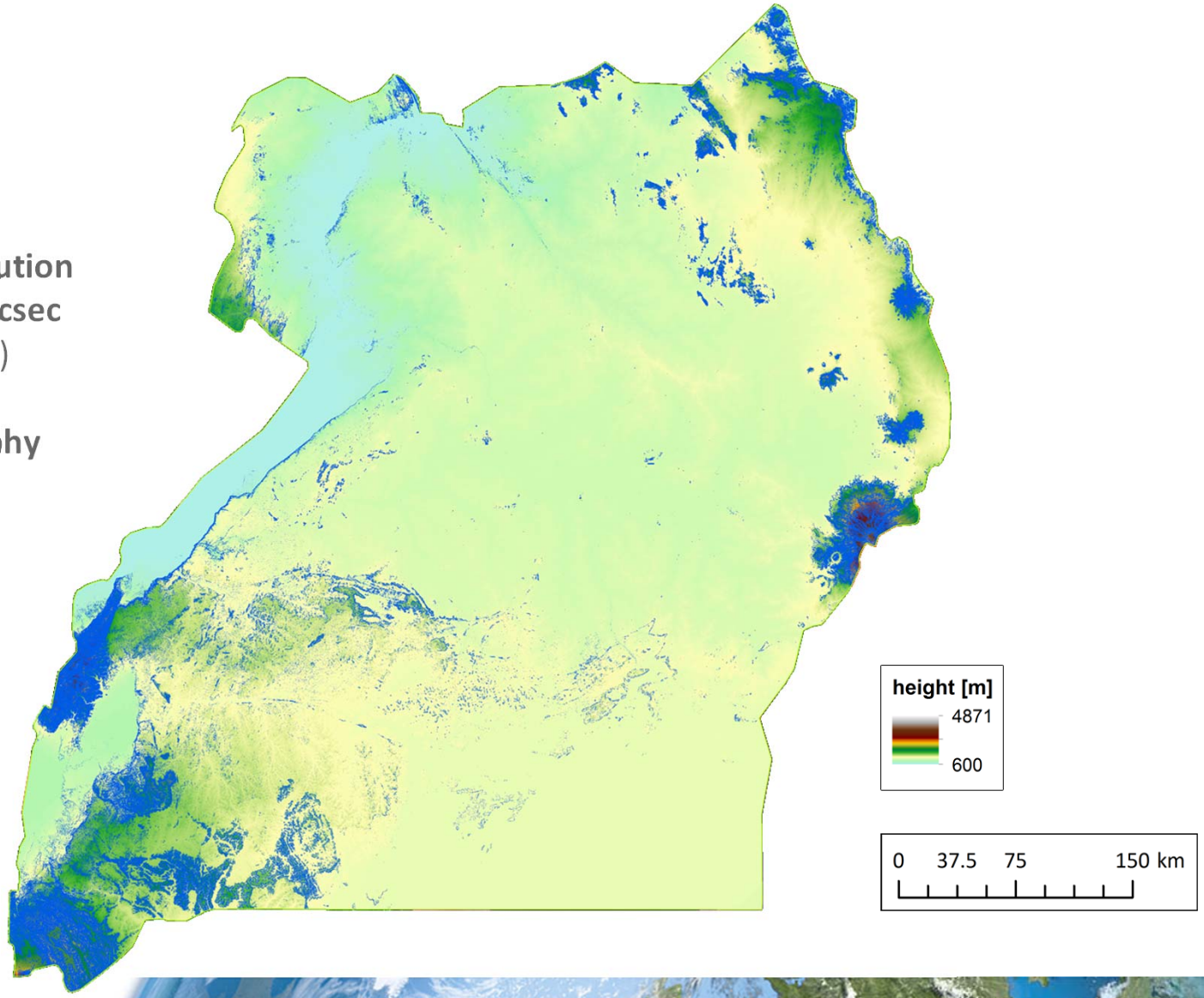


DLR

First Results

Uganda

High-Resolution
SRTM 1 arcsec
(~30 m)
+
topography
mask



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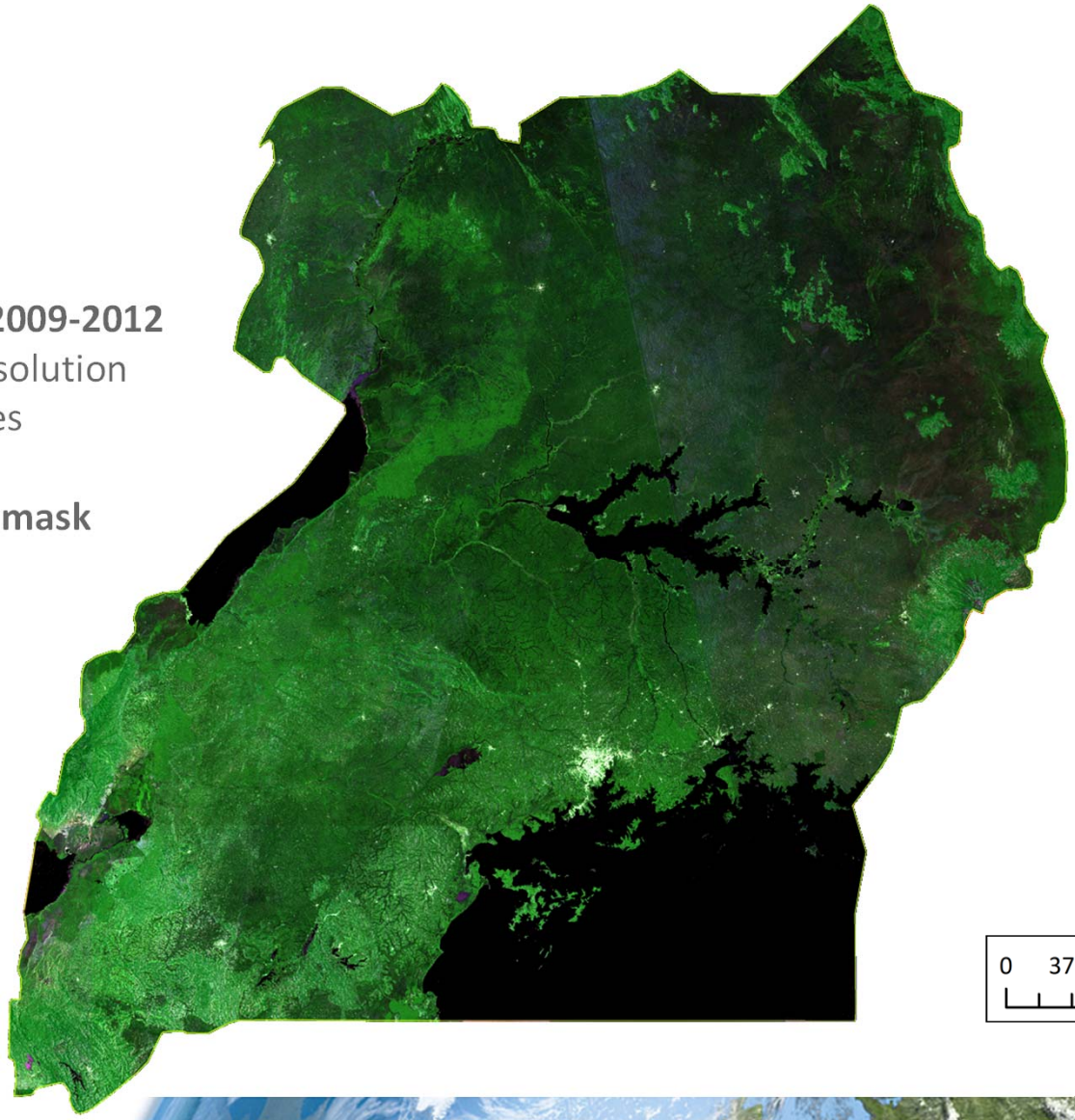


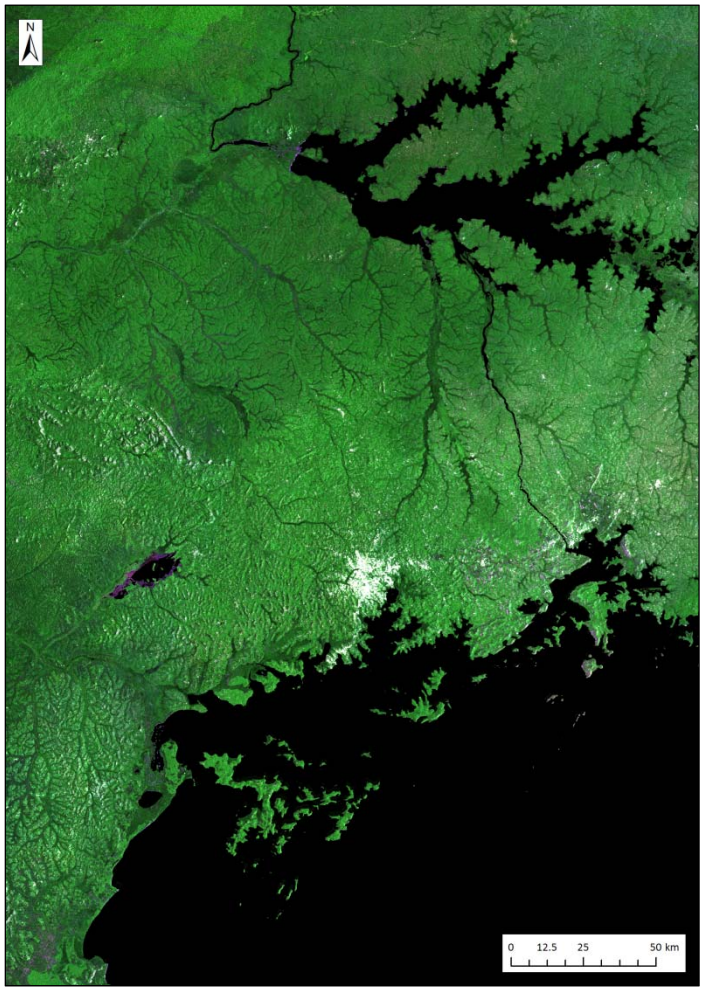
0 37.5 75 150 km

DLR

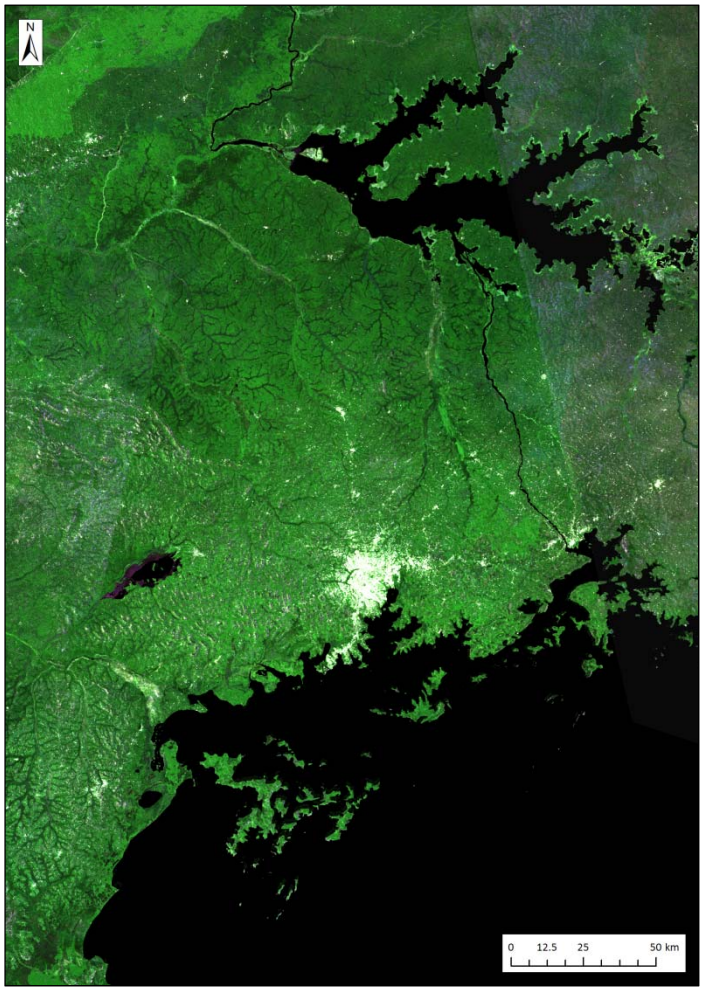
First Results

Kampala

ASAR WSM HH **2002-2003**



ASAR WSM HH **2009-2012**

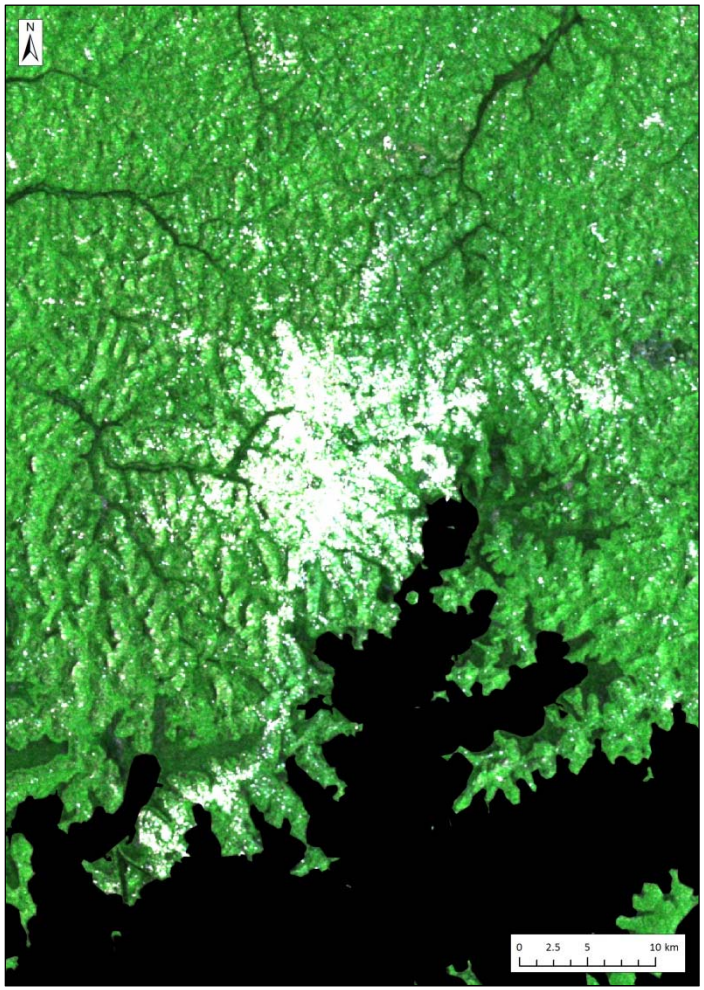


DLR

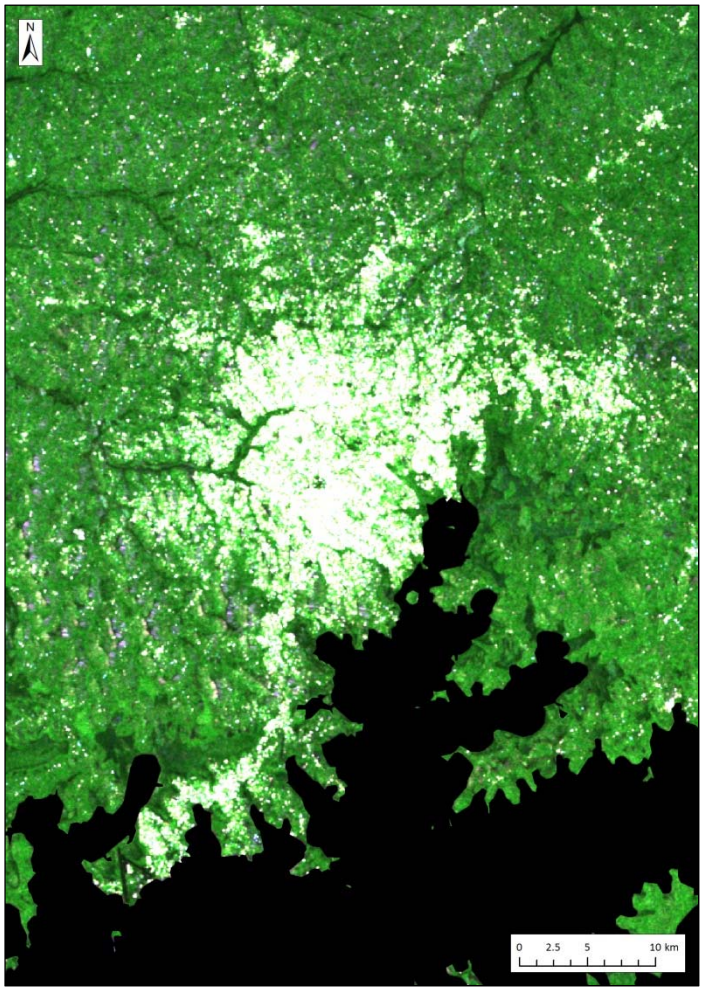
First Results

Kampala

ASAR WSM HH **2002-2003**



ASAR WSM HH **2009-2012**



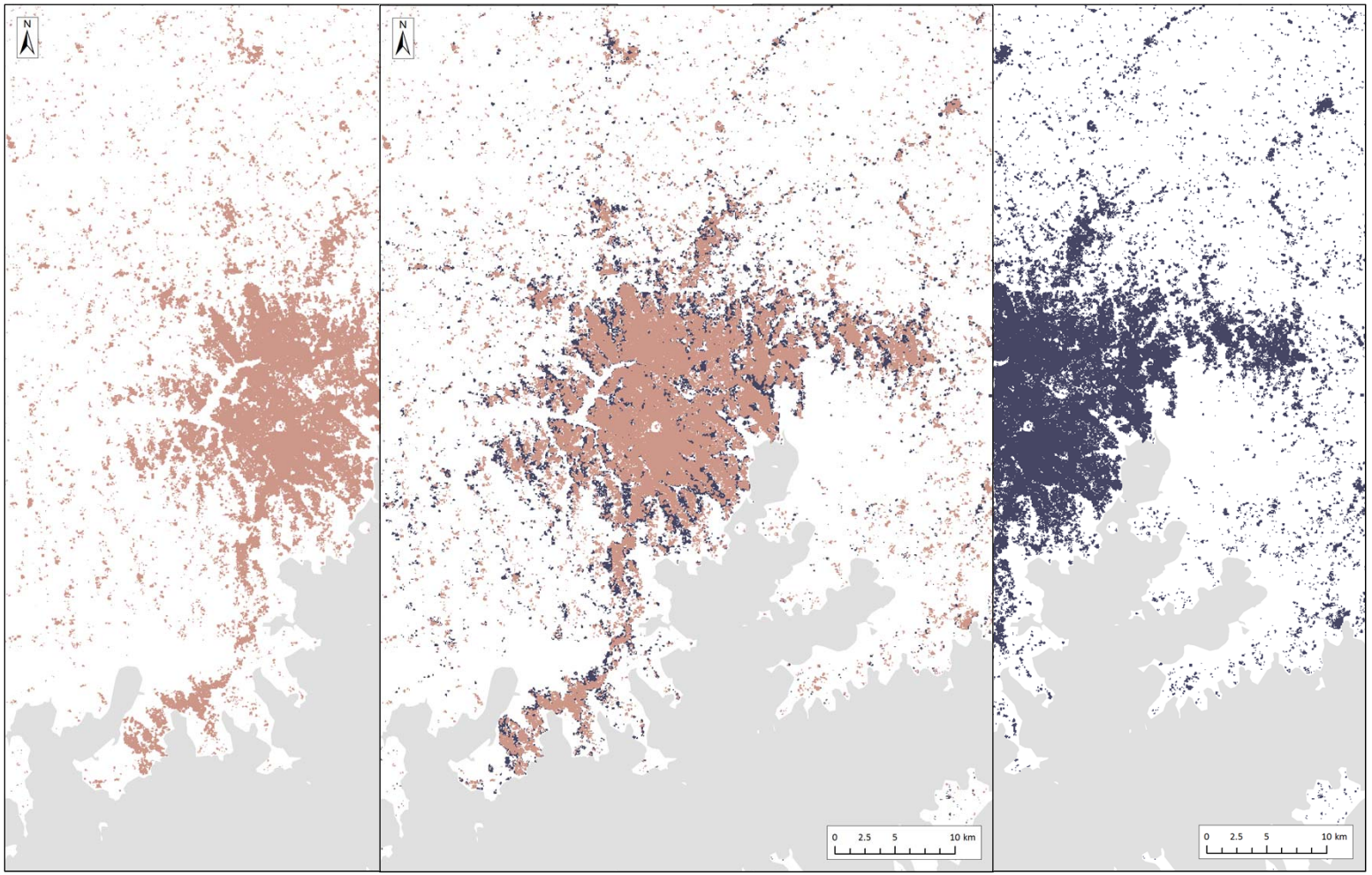
DLR

First Results

Kampala

2002-2003

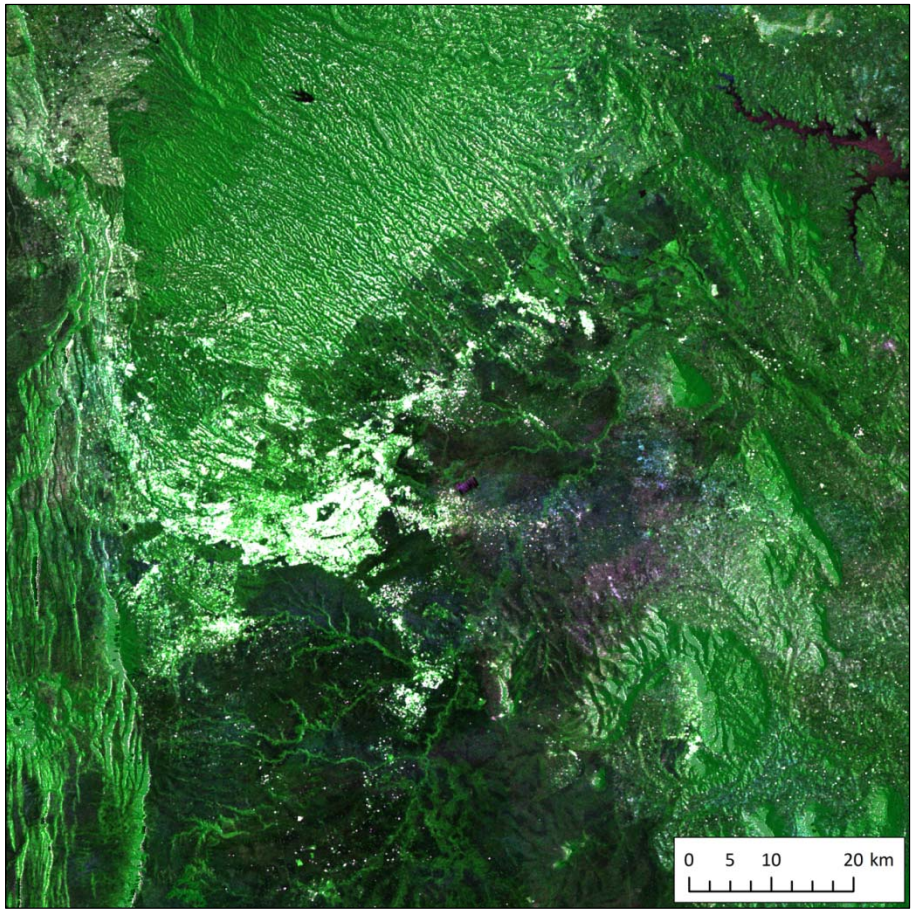
2009-2012



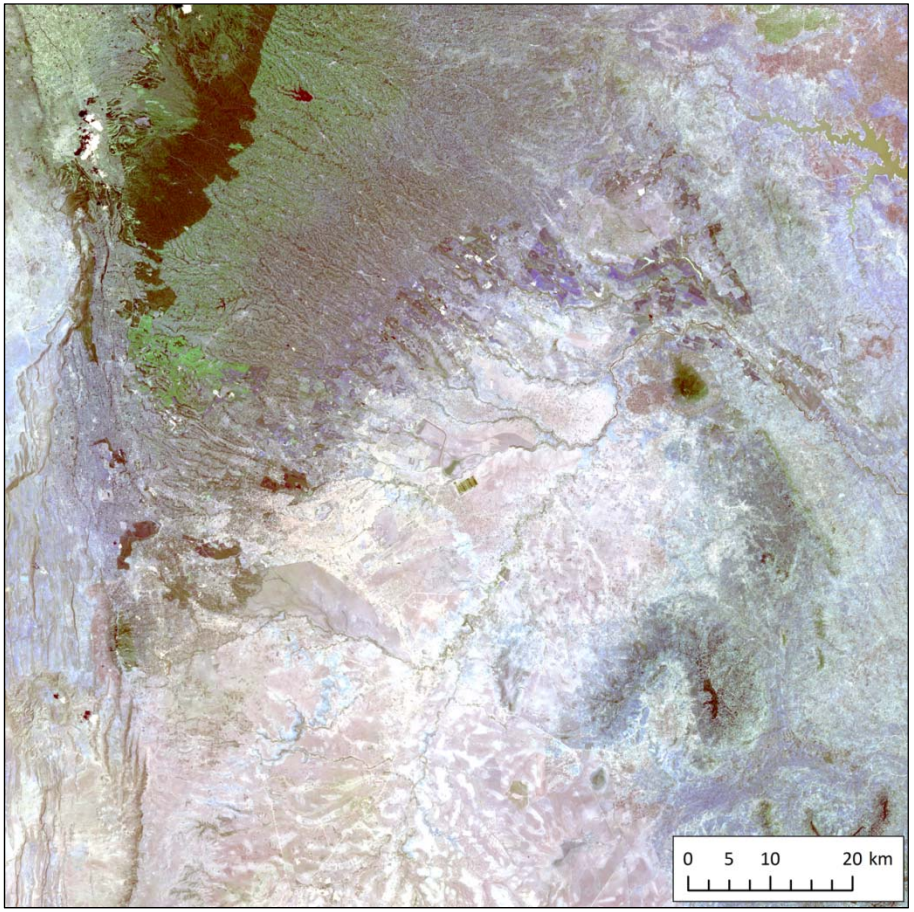
DLR

First Results

Nairobi



ASAR WSM HH 2009-2012

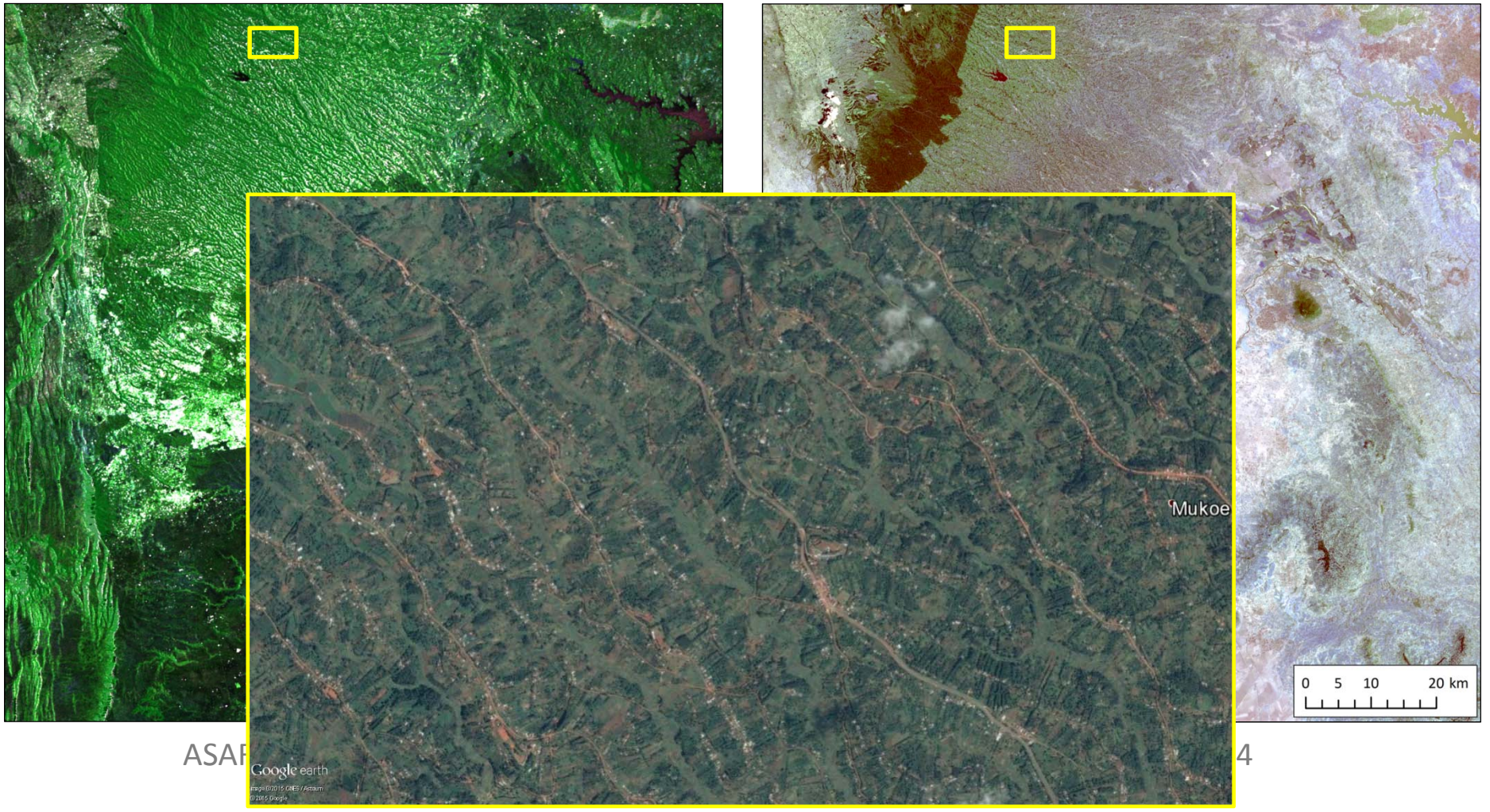


Landsat-8 OLI 2014

DLR

First Results

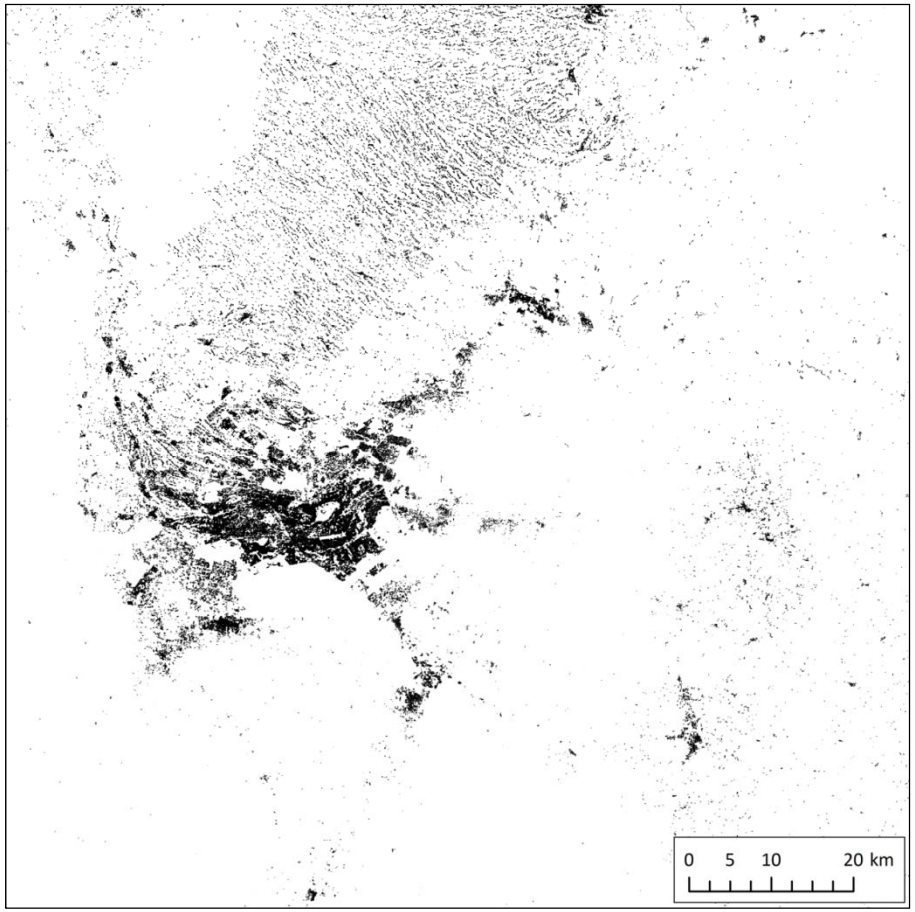
Nairobi

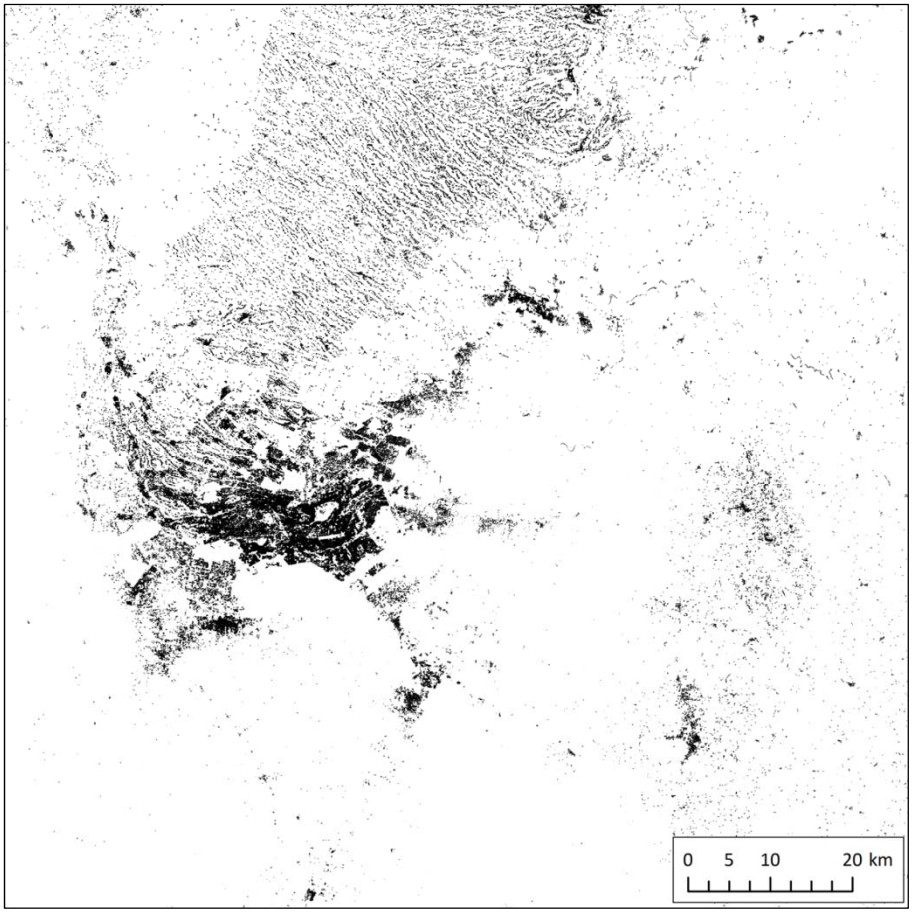


DLR

First Results

Nairobi





ASAR WSM HH 2009-2012
unsupervised method

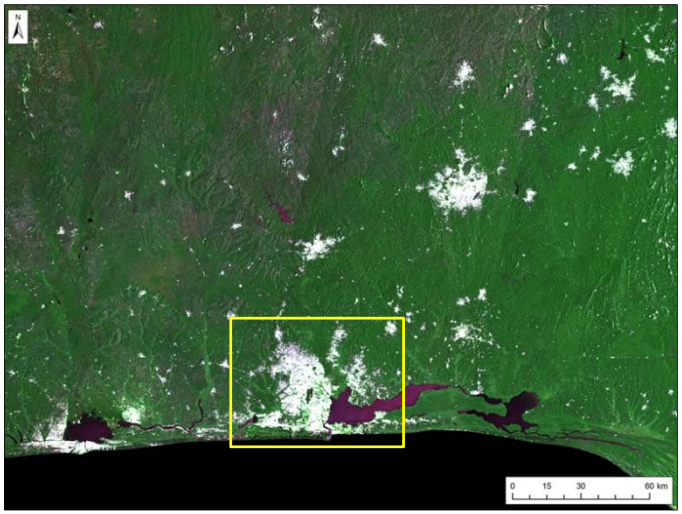
GAF

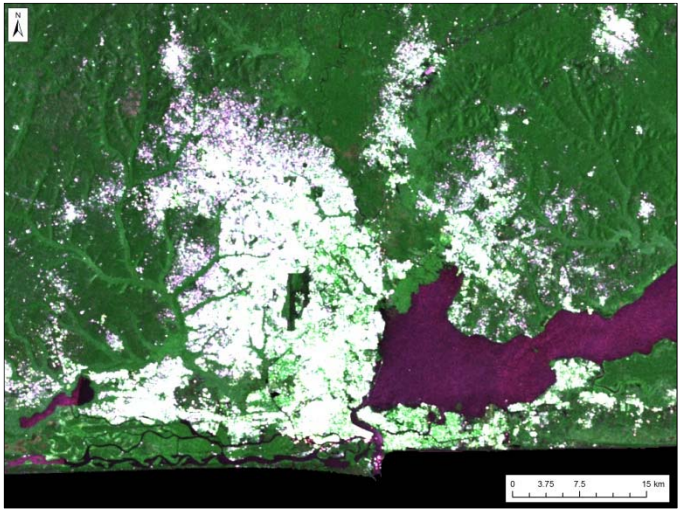
DLR

First Results

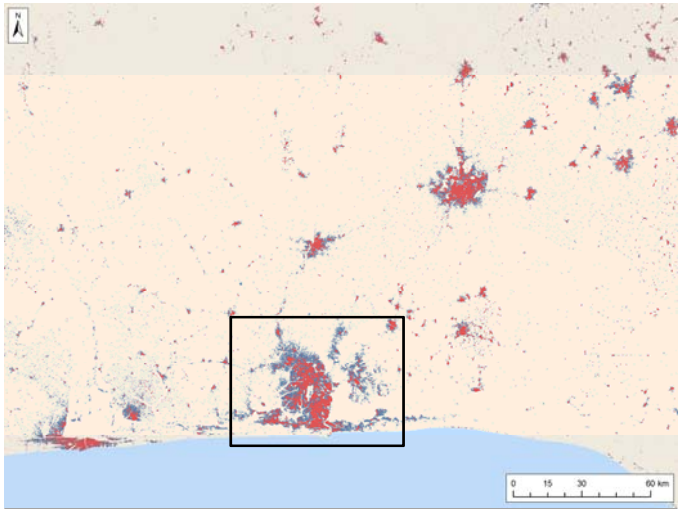
Benin

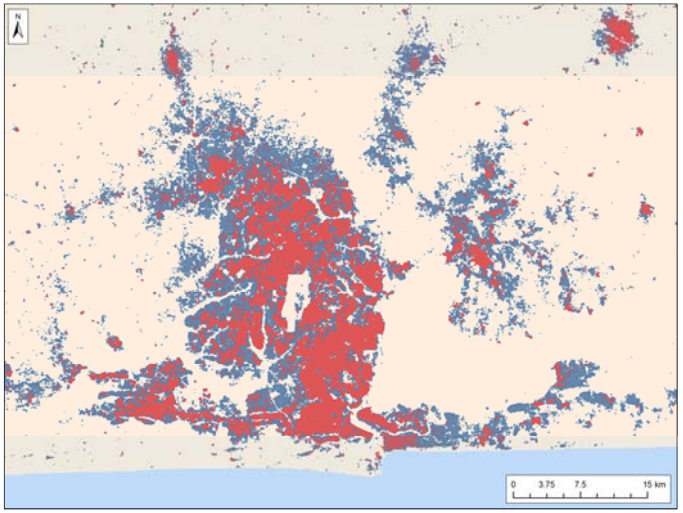
Nigeria





Lagos



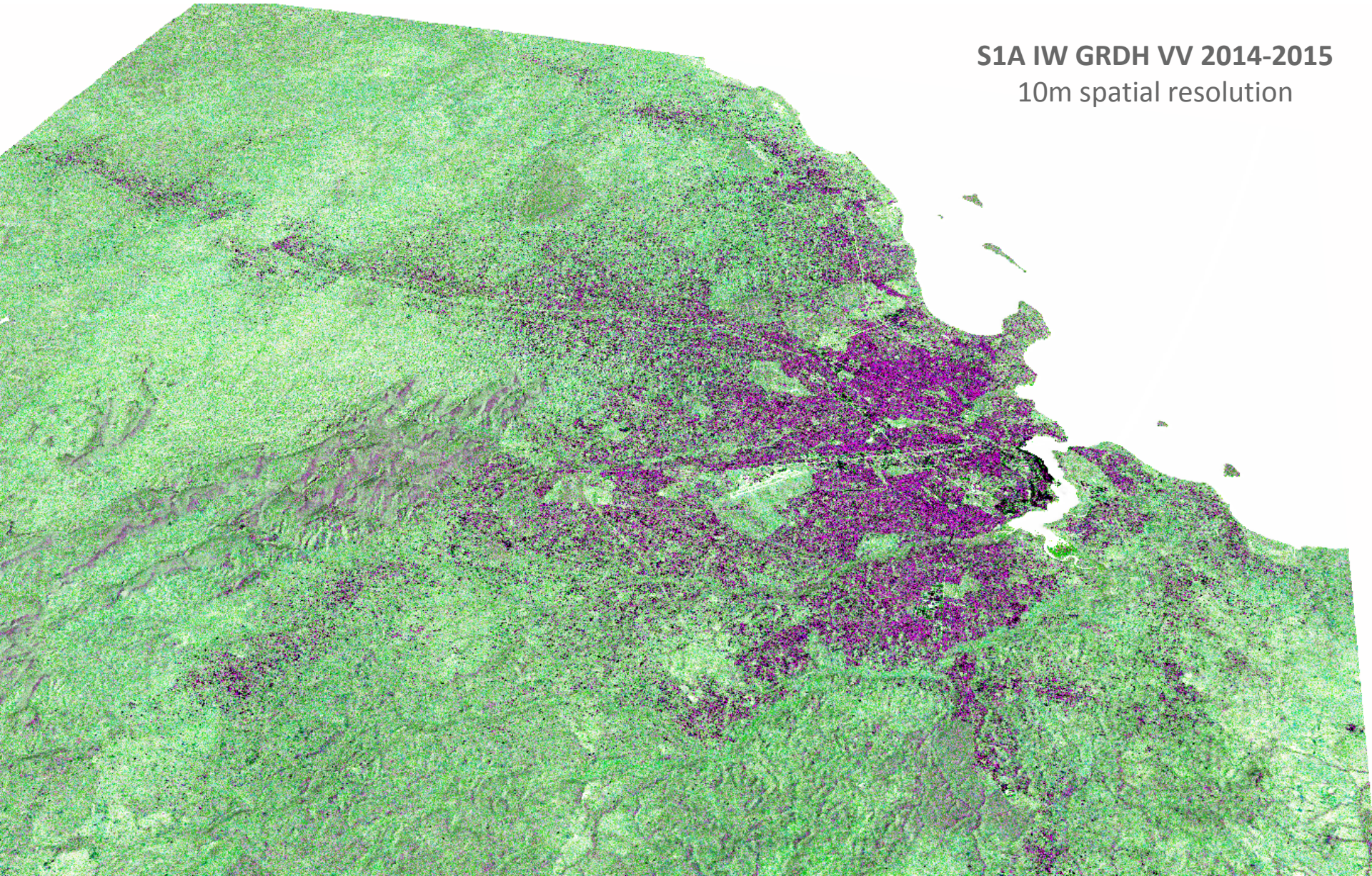


Non Urban
Urban 2003
Urban 2012

DLR

First Results

Dar es Salaam



S1A IW GRDH VV 2014-2015
10m spatial resolution

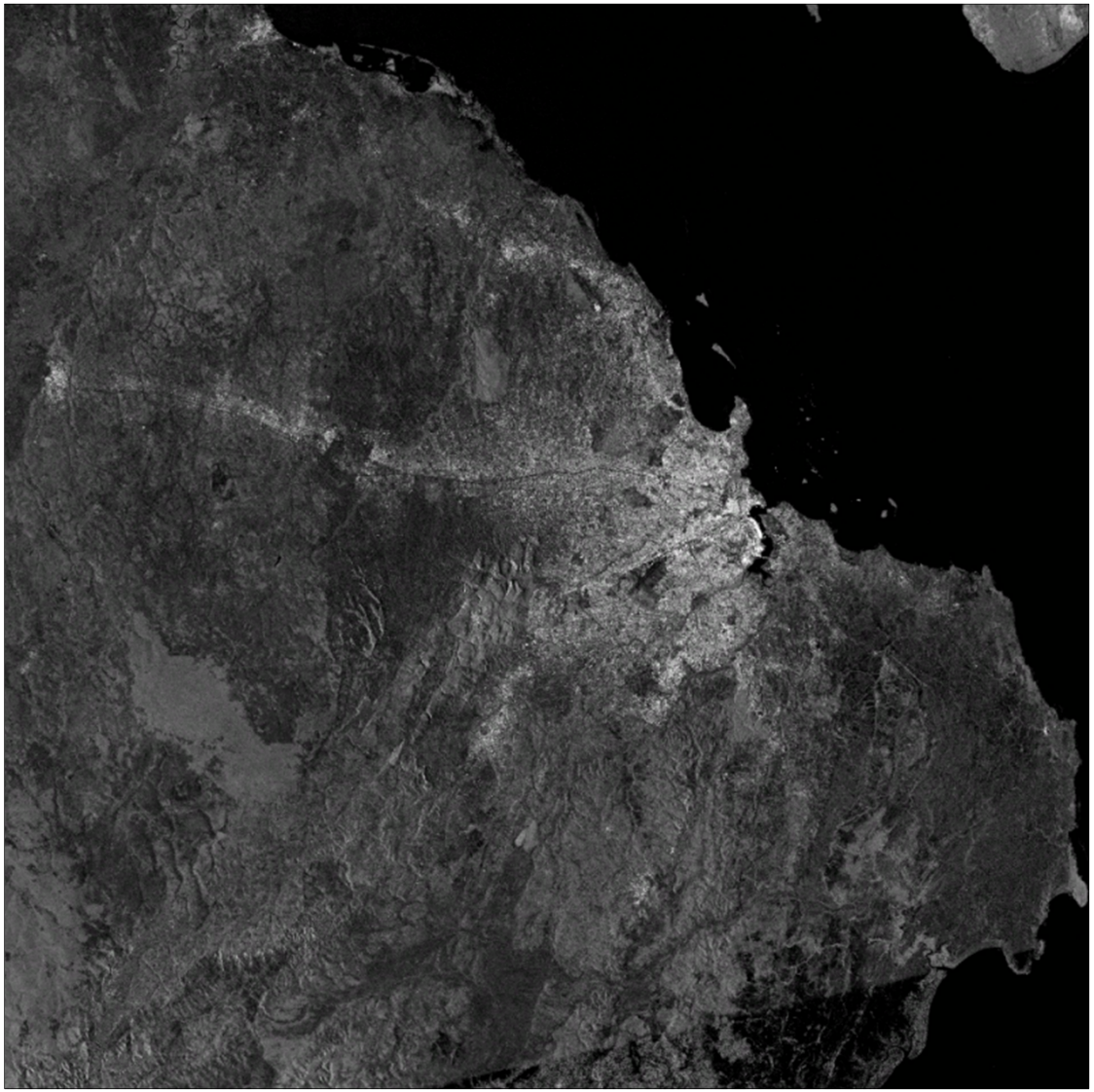
First Results

Dar es Salaam

Google Earth

First Results

Dar es Salaam

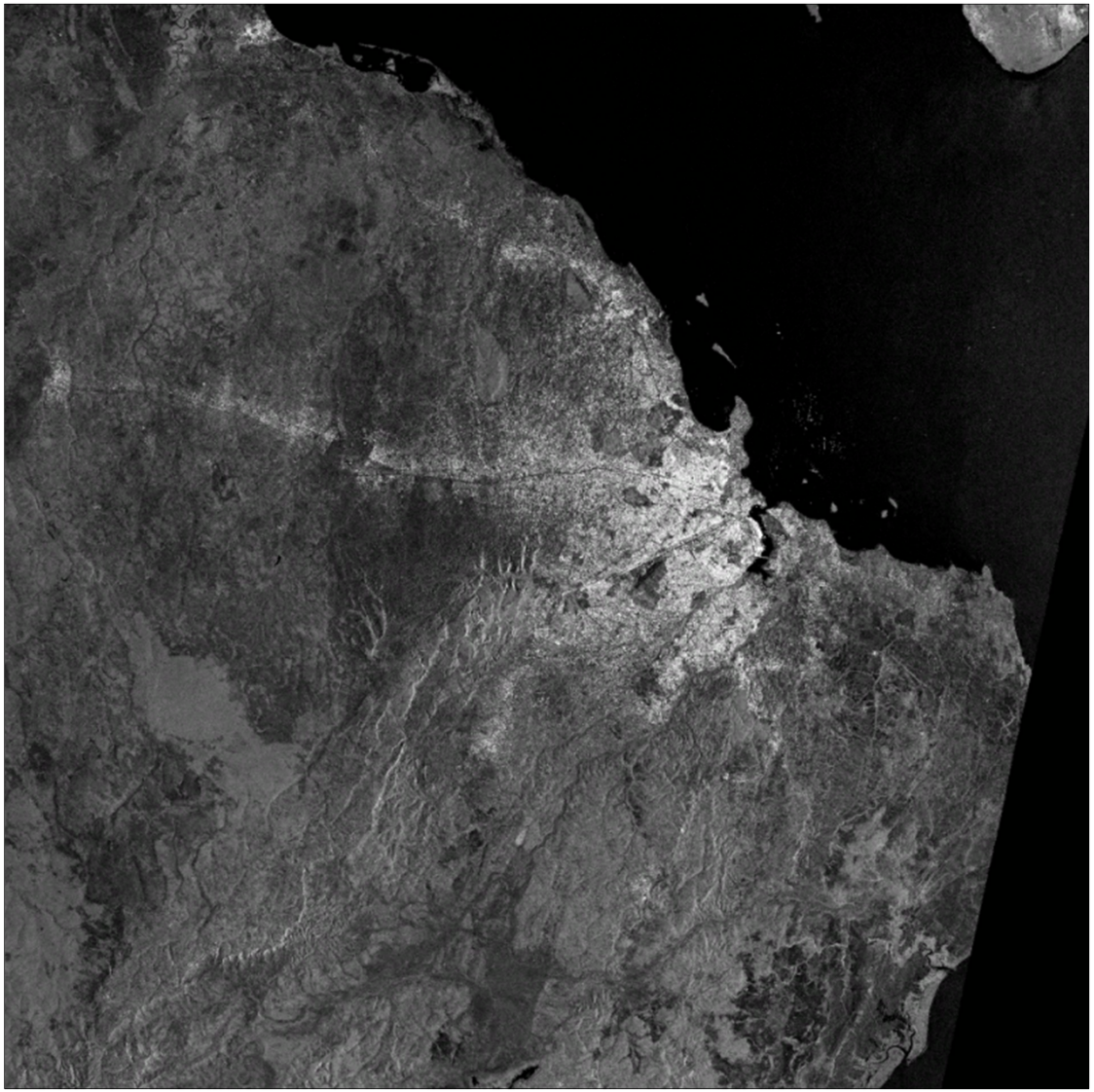


S1A IW GRDH VV
2014-2015
10m spatial resolution
13 scenes
ASCENDING PASS
Temporal Mean

DLR

First Results

Dar es Salaam

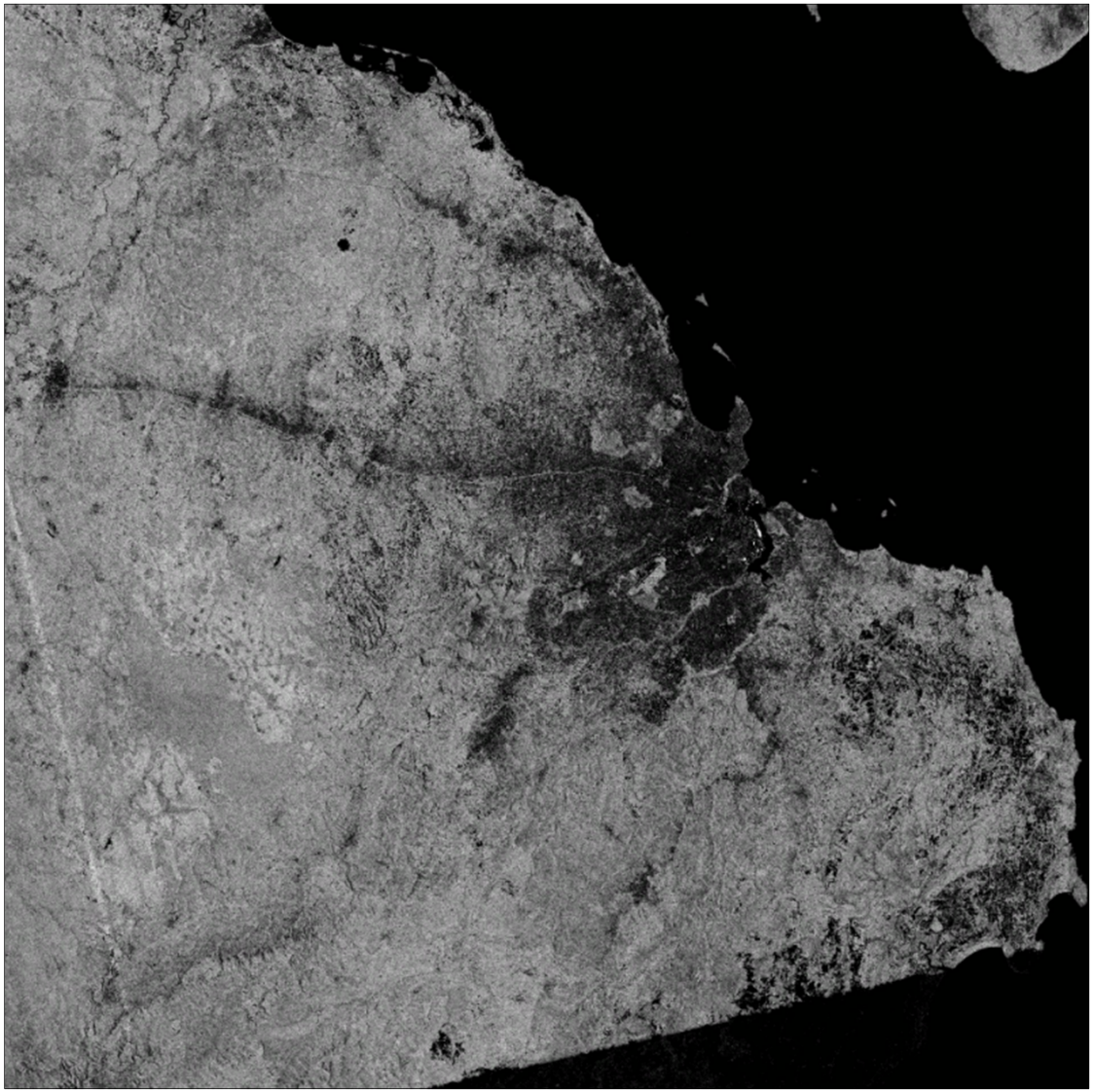


S1A IW GRDH VV
2014-2015
10m spatial resolution
24 scenes
DESCENDING PASS
Temporal Mean

DLR

First Results

Dar es Salaam

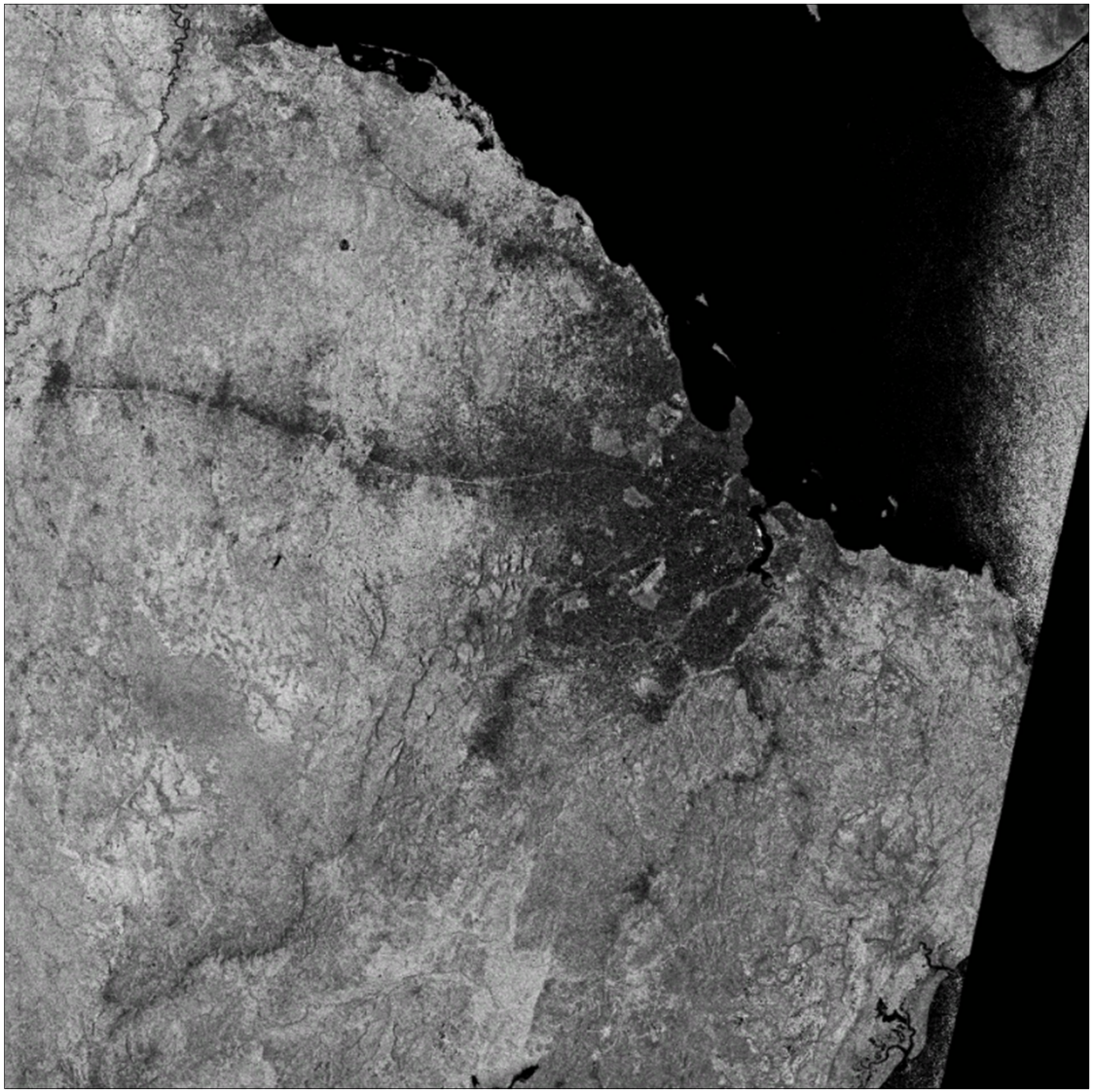


S1A IW GRDH VV
2014-2015
10m spatial resolution
13 scenes
ASCENDING PASS
COV 5x5

DLR

First Results

Dar es Salaam



S1A IW GRDH VV
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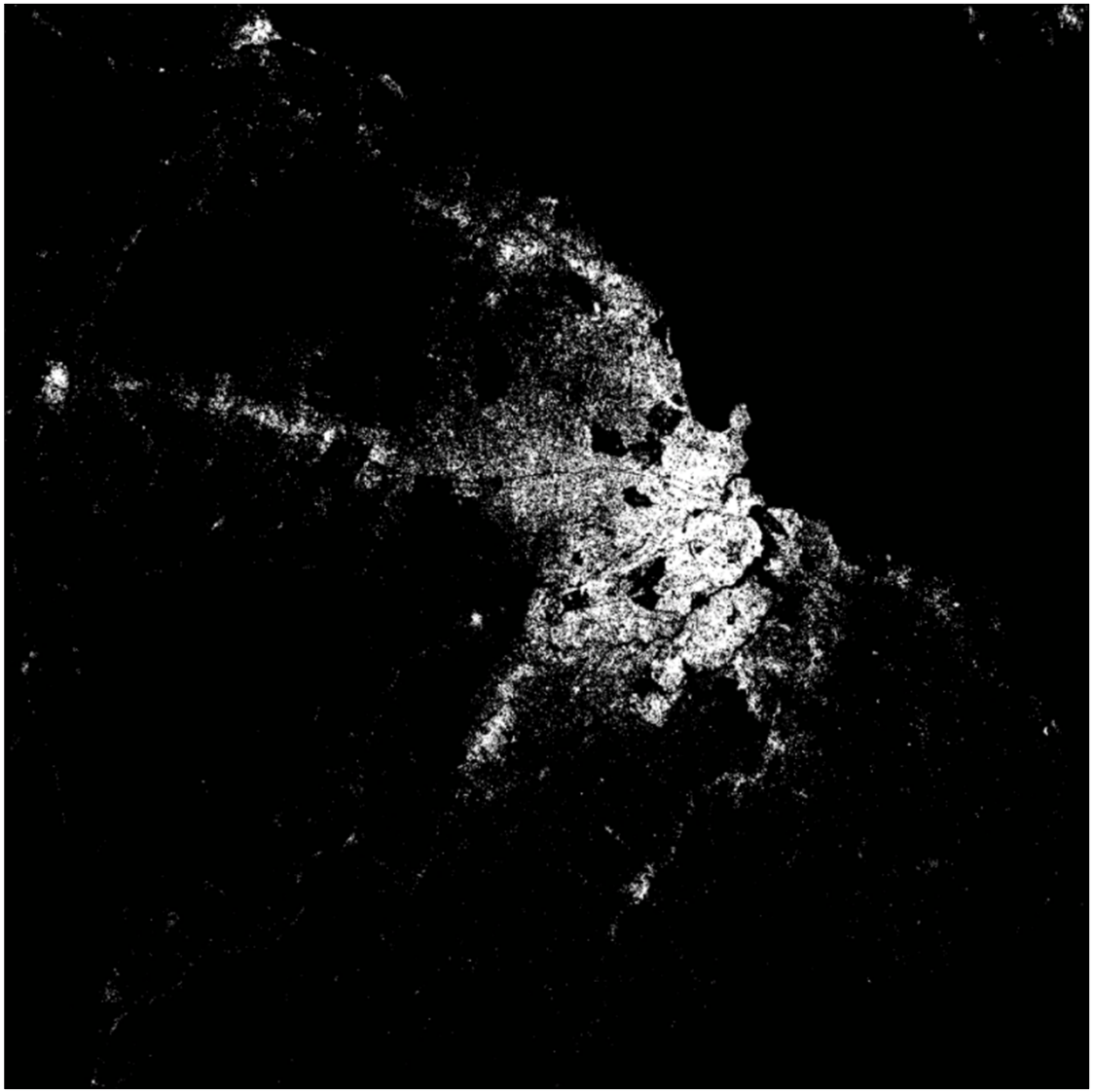
DLR

First Results

Dar es Salaam



S1A IW GRDH VV
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10m spatial resolution
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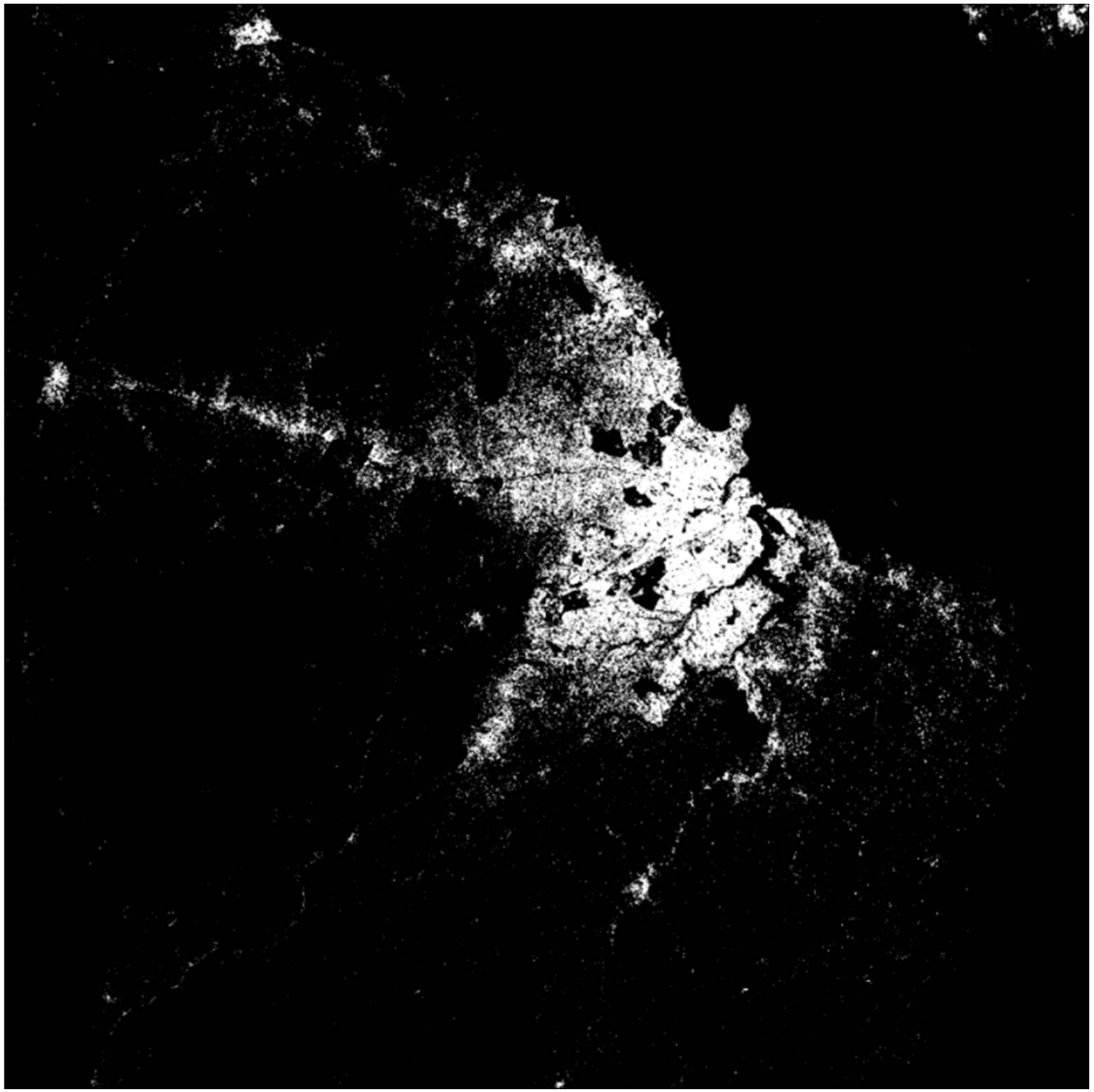
ASCENDING PASS
Unsupervised Method

DLR

First Results

Dar es Salaam



S1A IW GRDH VV
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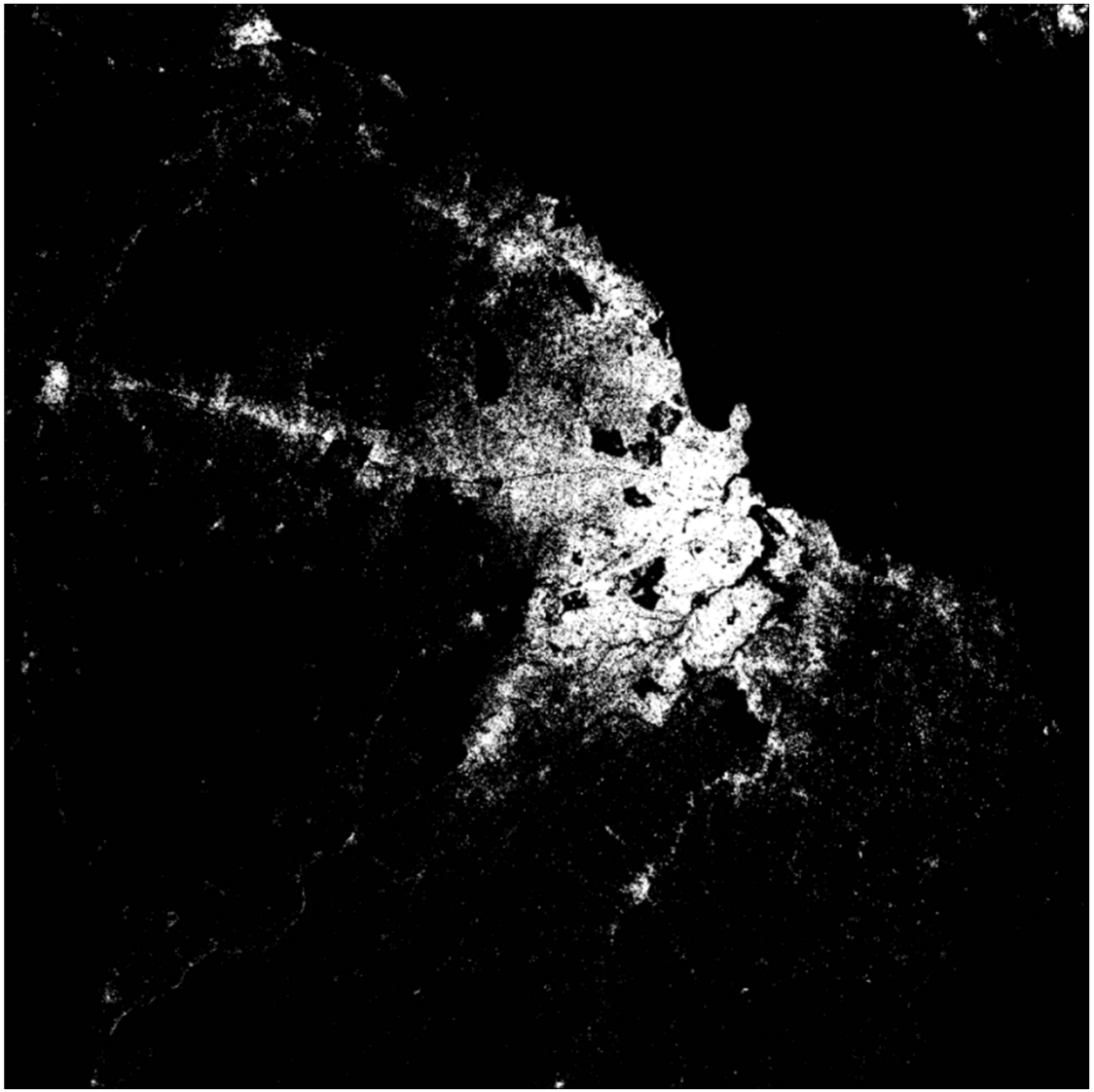
10m spatial resolution
24 scenes
DESCENDING PASS
Unsupervised Method

DLR

First Results

Dar es Salaam

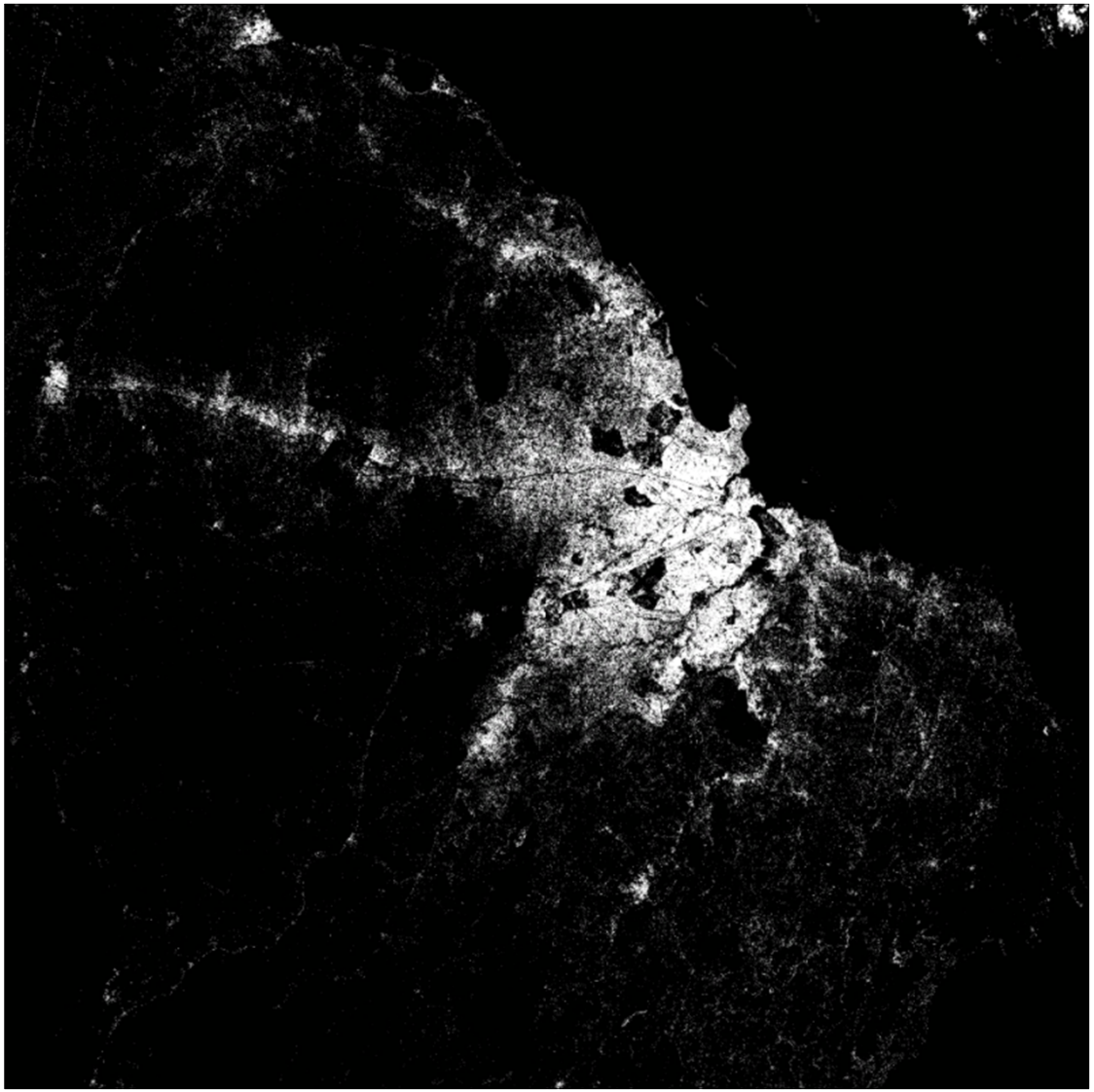


S1A IW GRDH VV
2014-2015
10m spatial resolution
combination
ASCENDING +
DESCENDING PASS
Unsupervised Method

DLR

First Results

Dar es Salaam

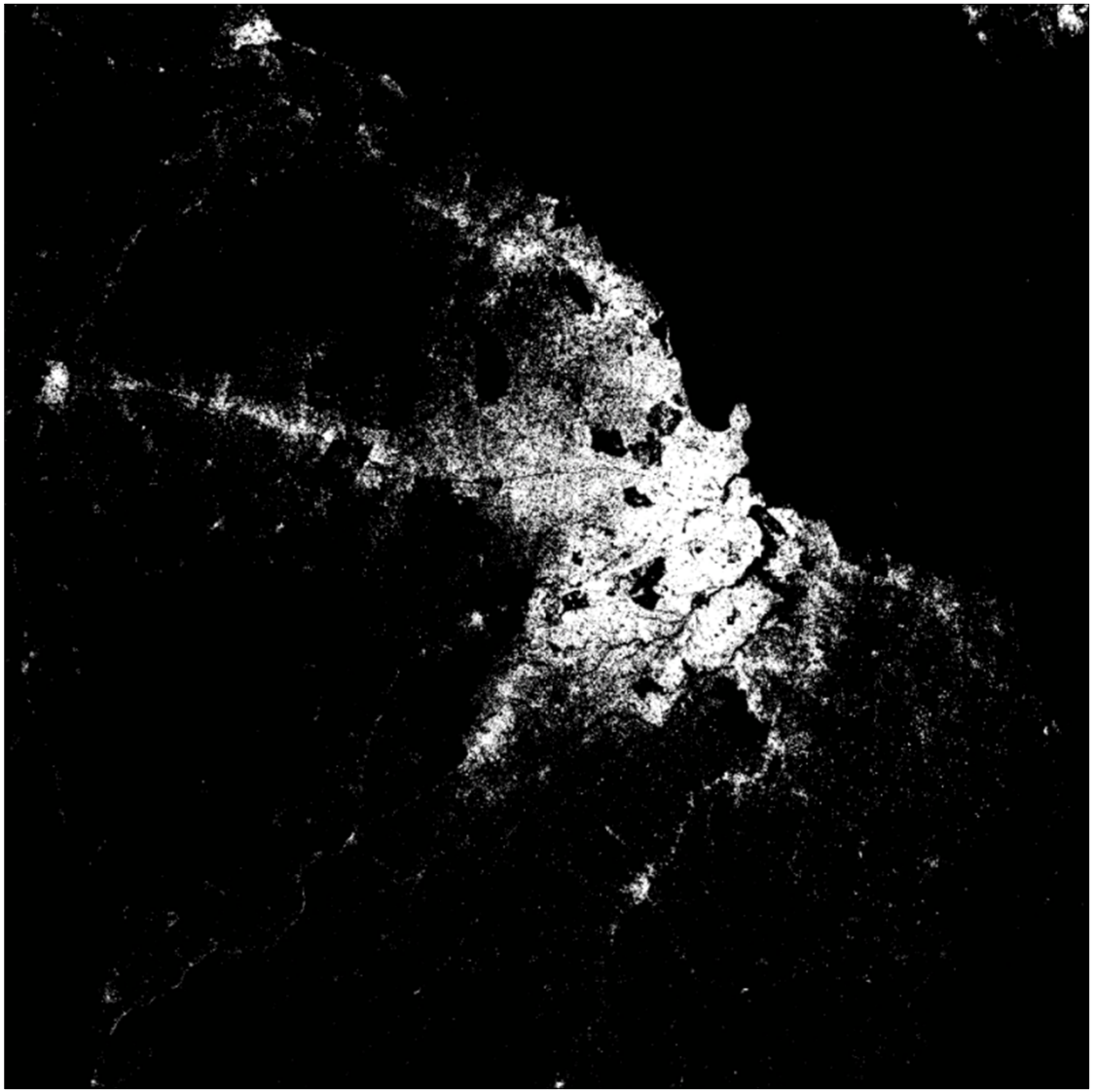


S1A IW GRDH VV
2014-2015
10m spatial resolution
combination
ASCENDING +
DESCENDING PASS
Supervised Method

DLR

First Results

Dar es Salaam

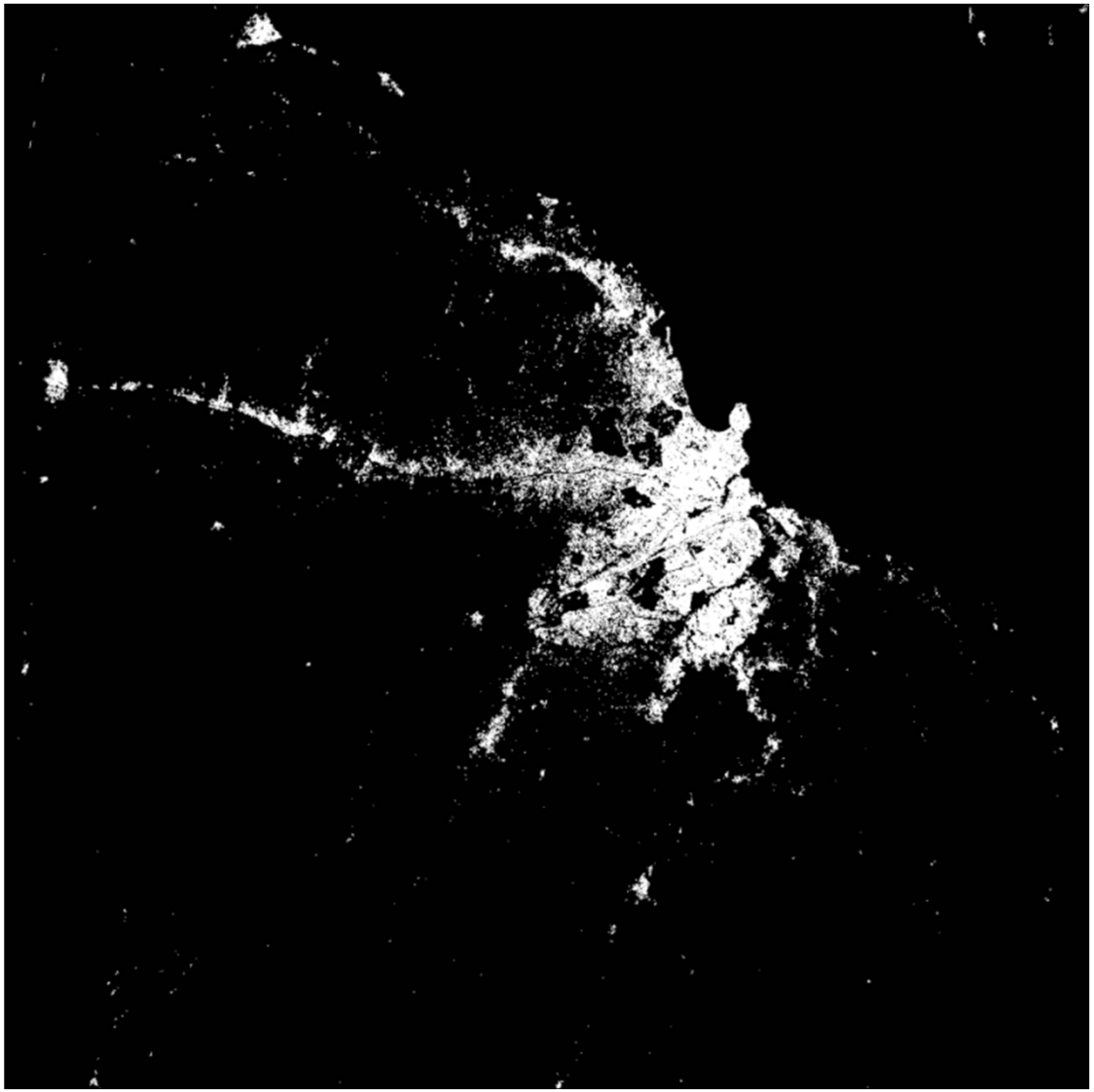


S1A IW GRDH VV
2014-2015
10m spatial resolution
combination
ASCENDING +
DESCENDING PASS
Unsupervised Method

DLR

First Results

Dar es Salaam



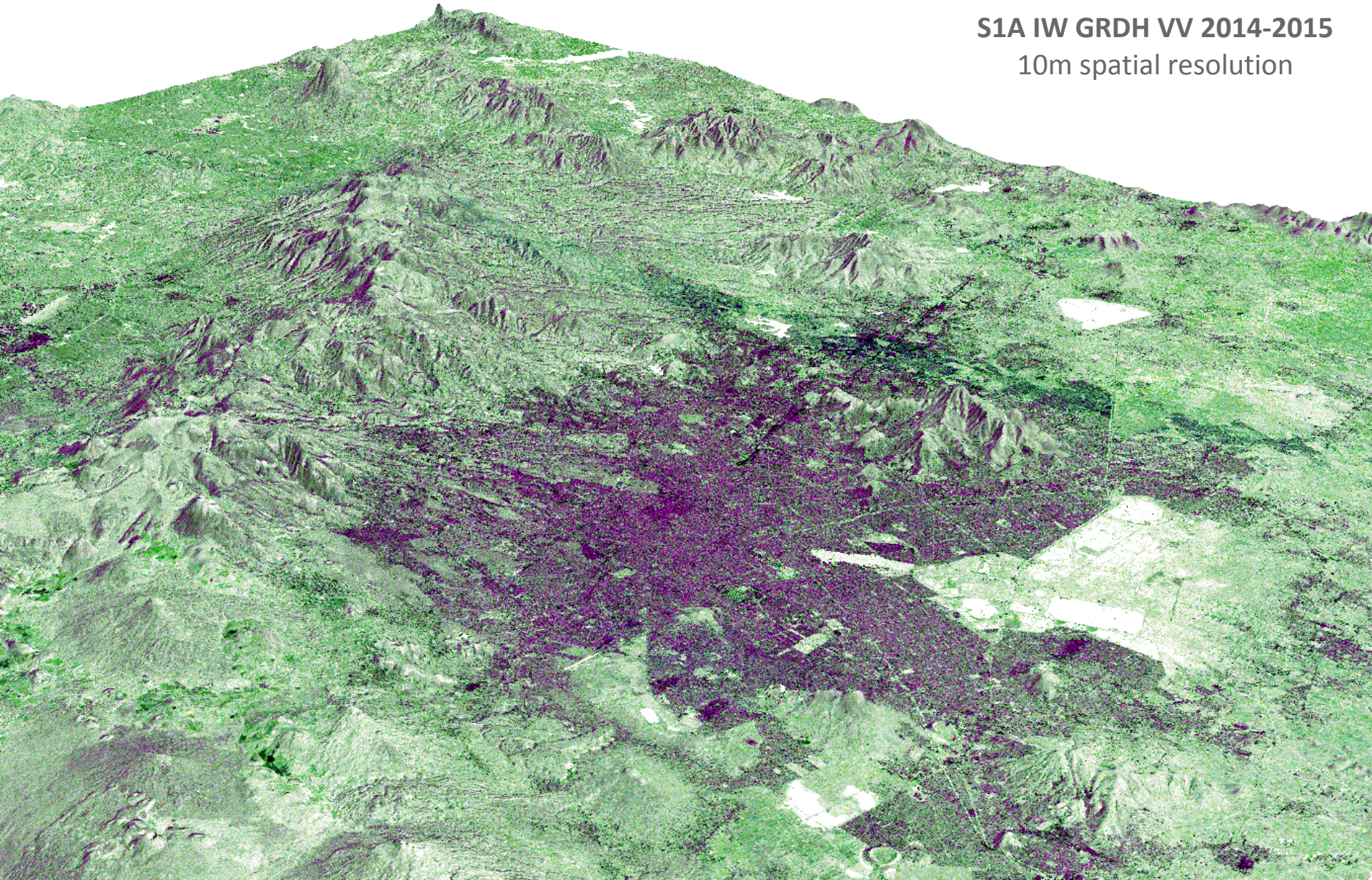
GOF

DLR

First Results

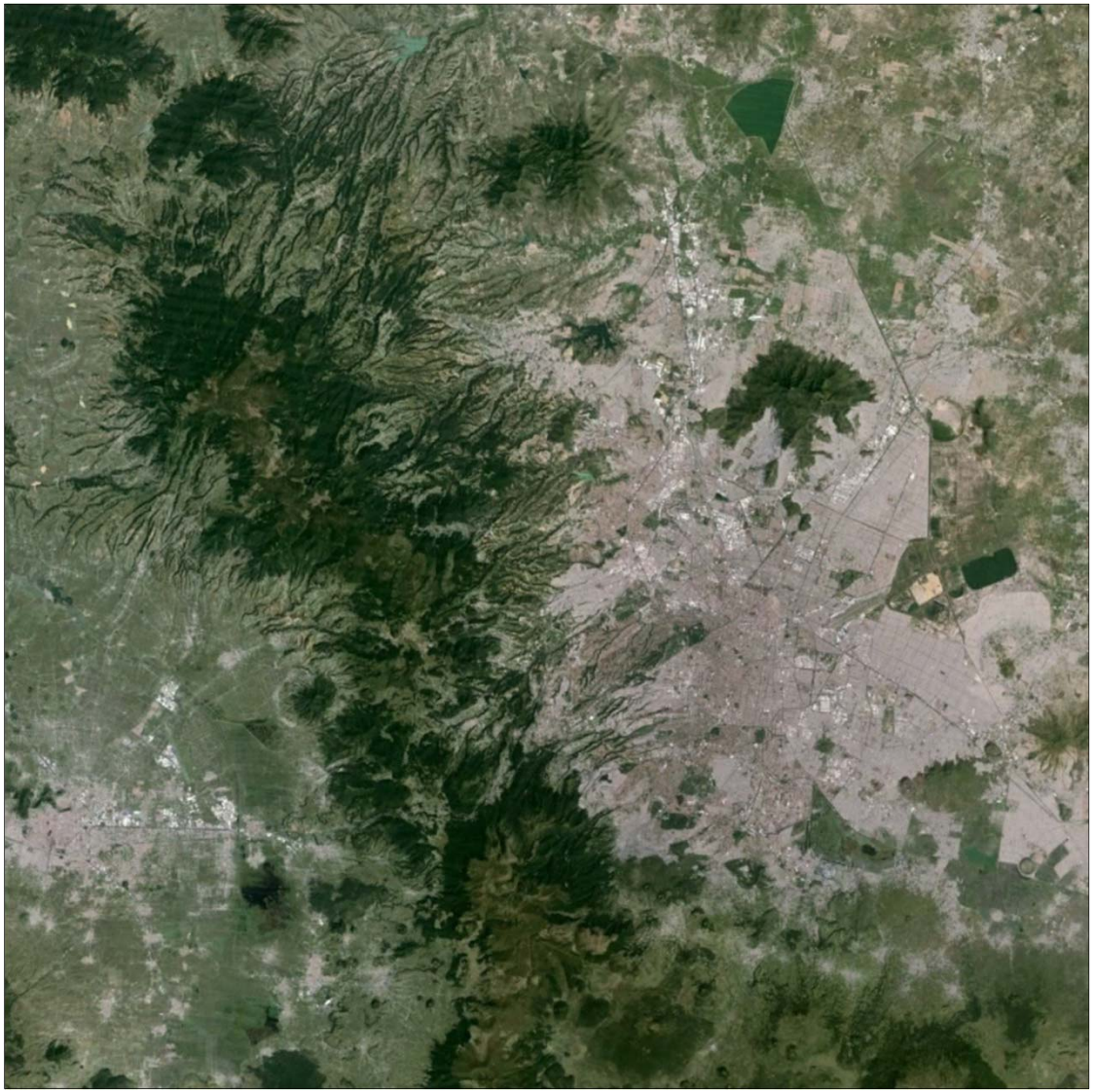
Mexico City

S1A IW GRDH VV 2014-2015
10m spatial resolution



First Results

Mexico City

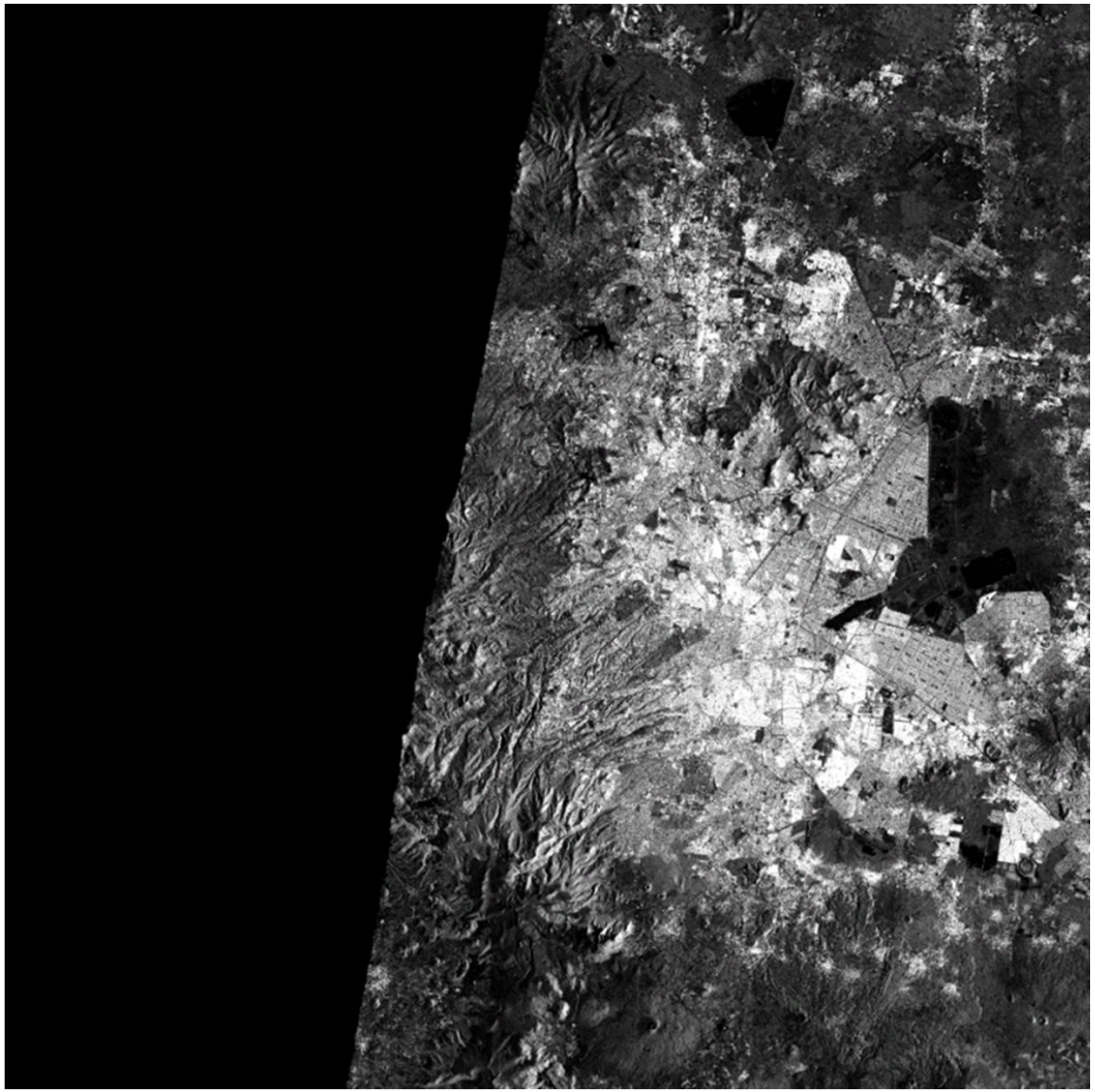


Google Earth

DLR

First Results

Mexico City

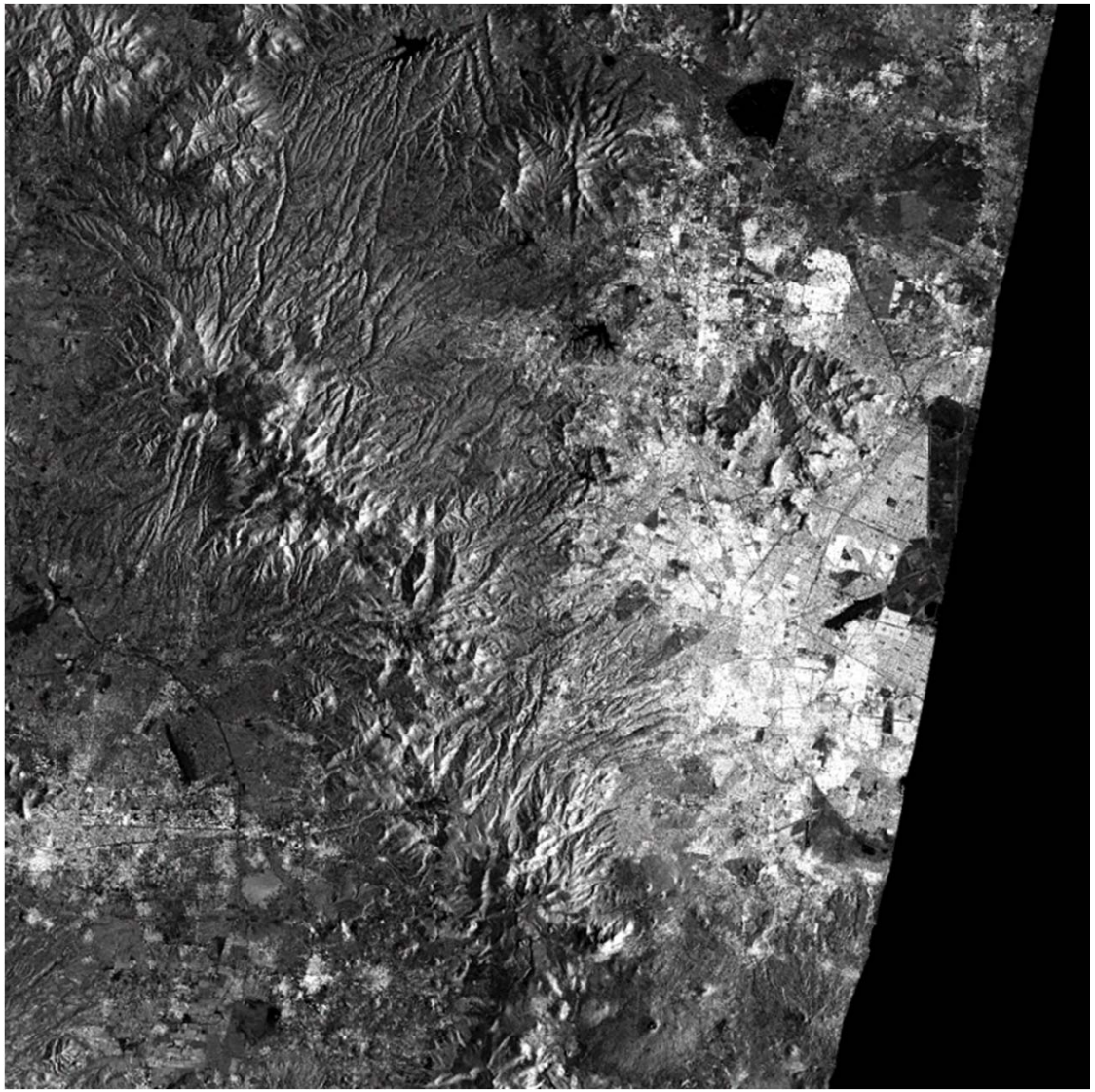


S1A IW GRDH VV
2014-2015
10m spatial resolution
40 scenes
DESCENDING PASS | 143
Temporal Mean

DLR

First Results

Mexico City

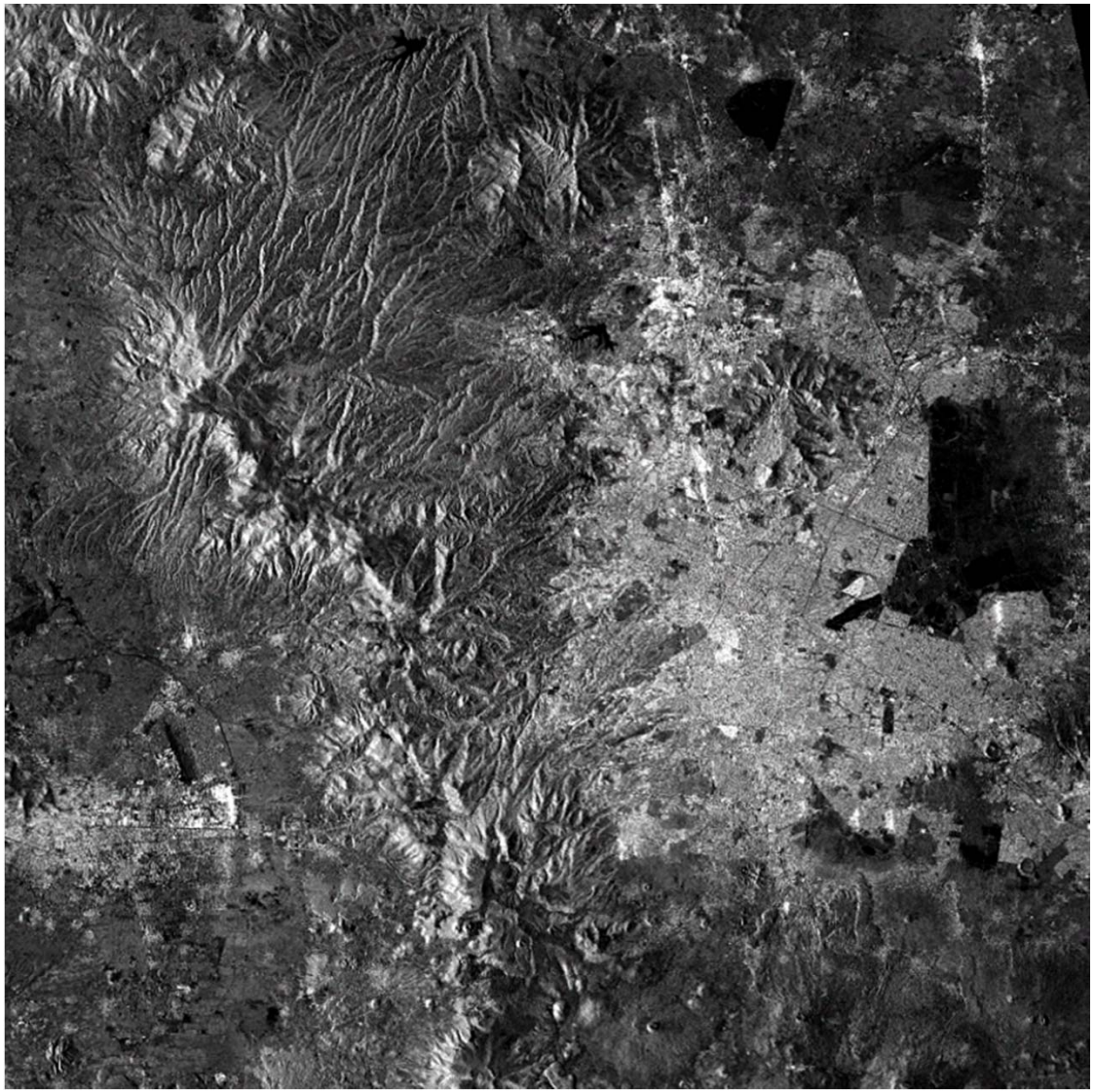


S1A IW GRDH VV
2014-2015
10m spatial resolution
40 scenes
DESCENDING PASS | 41
Temporal Mean

DLR

First Results

Mexico City

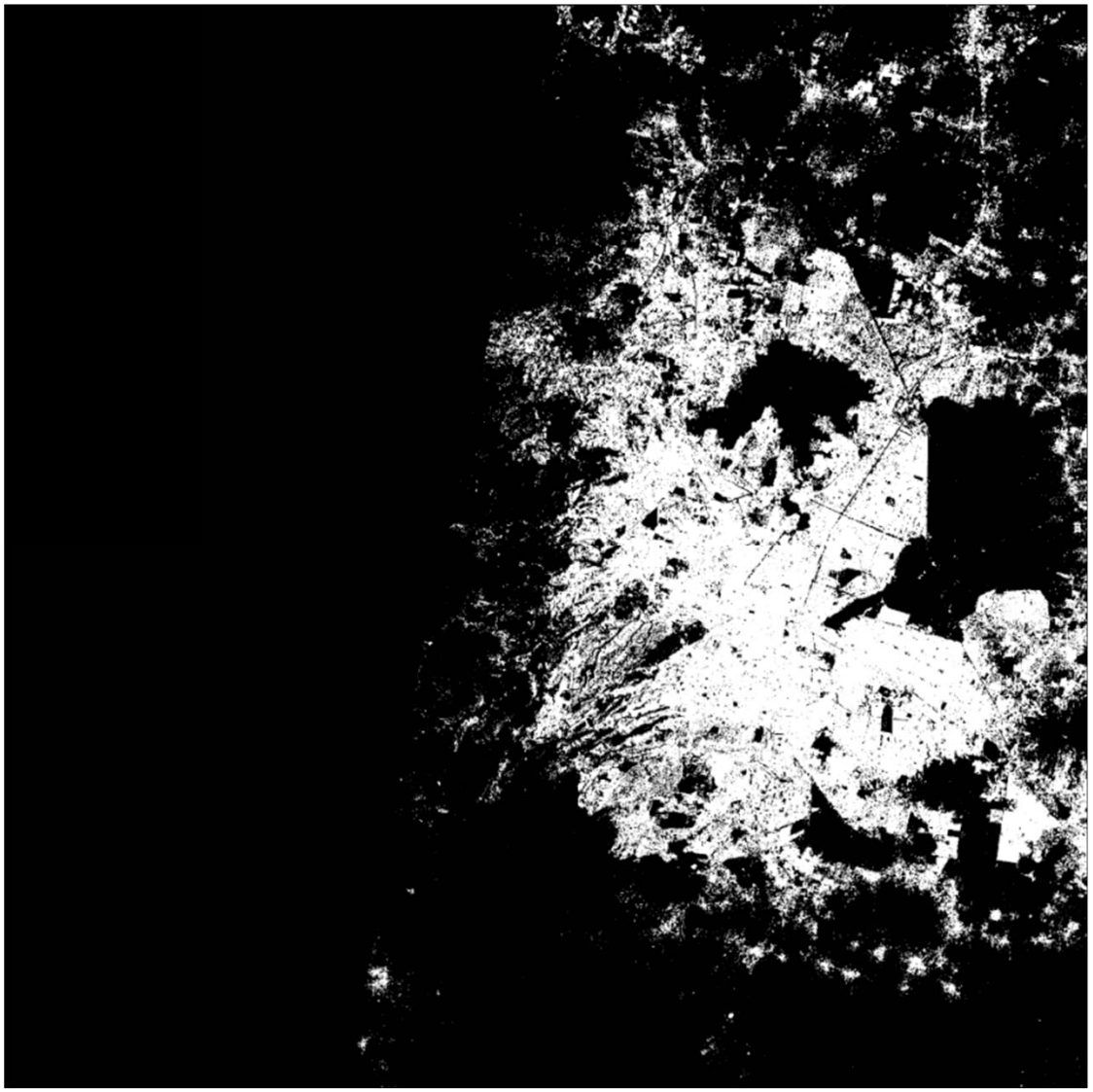


S1A IW GRDH VV
2014-2015
10m spatial resolution
30 scenes
ASCENDING PASS
Temporal Mean

DLR

First Results

Mexico City

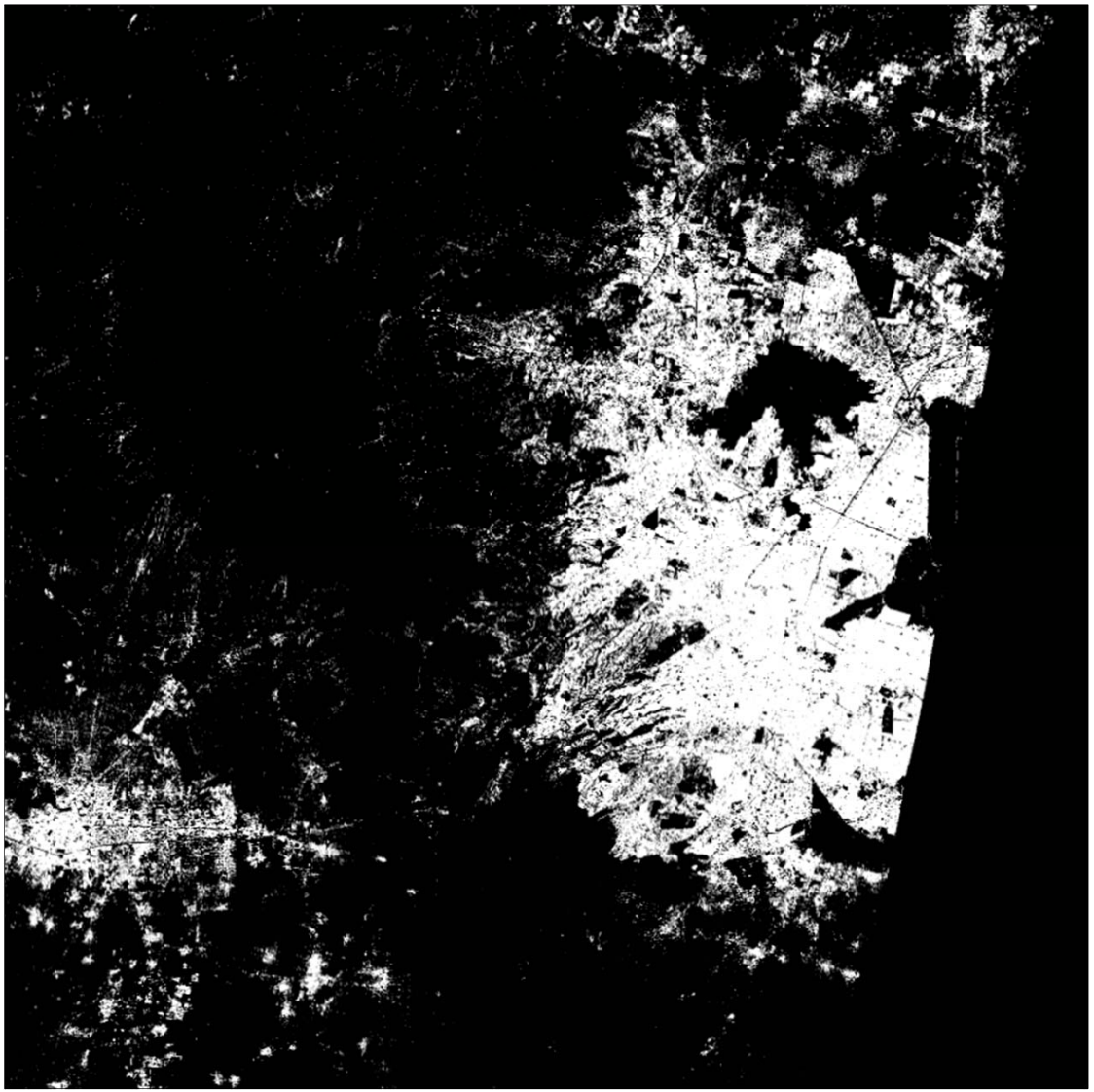


S1A IW GRDH VV
2014-2015
10m spatial resolution
40 scenes
DESCENDING PASS | 143
Unsupervised Method

DLR

First Results

Mexico City

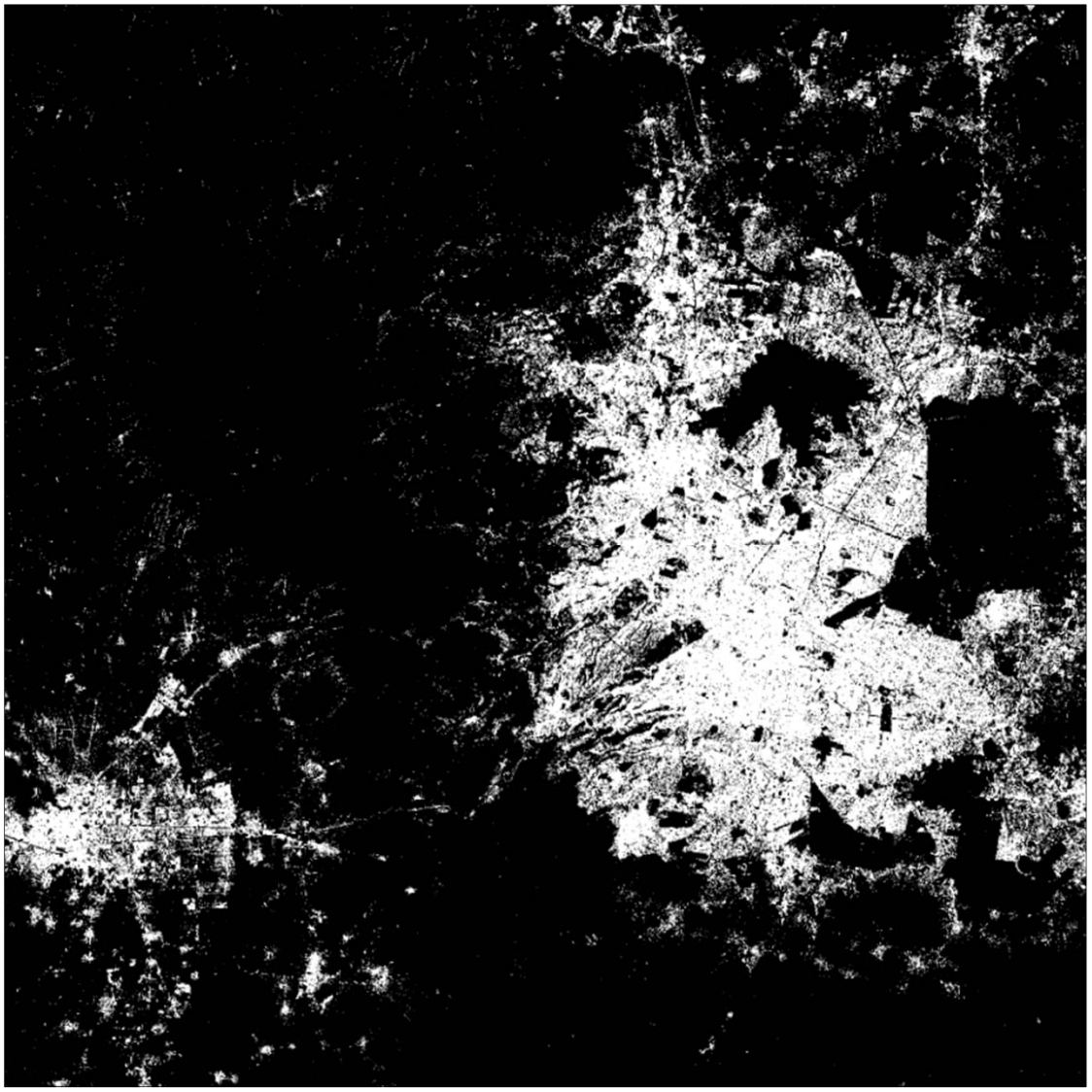


S1A IW GRDH VV
2014-2015
10m spatial resolution
40 scenes
DESCENDING PASS | 41
Unsupervised Method

DLR

First Results

Mexico City

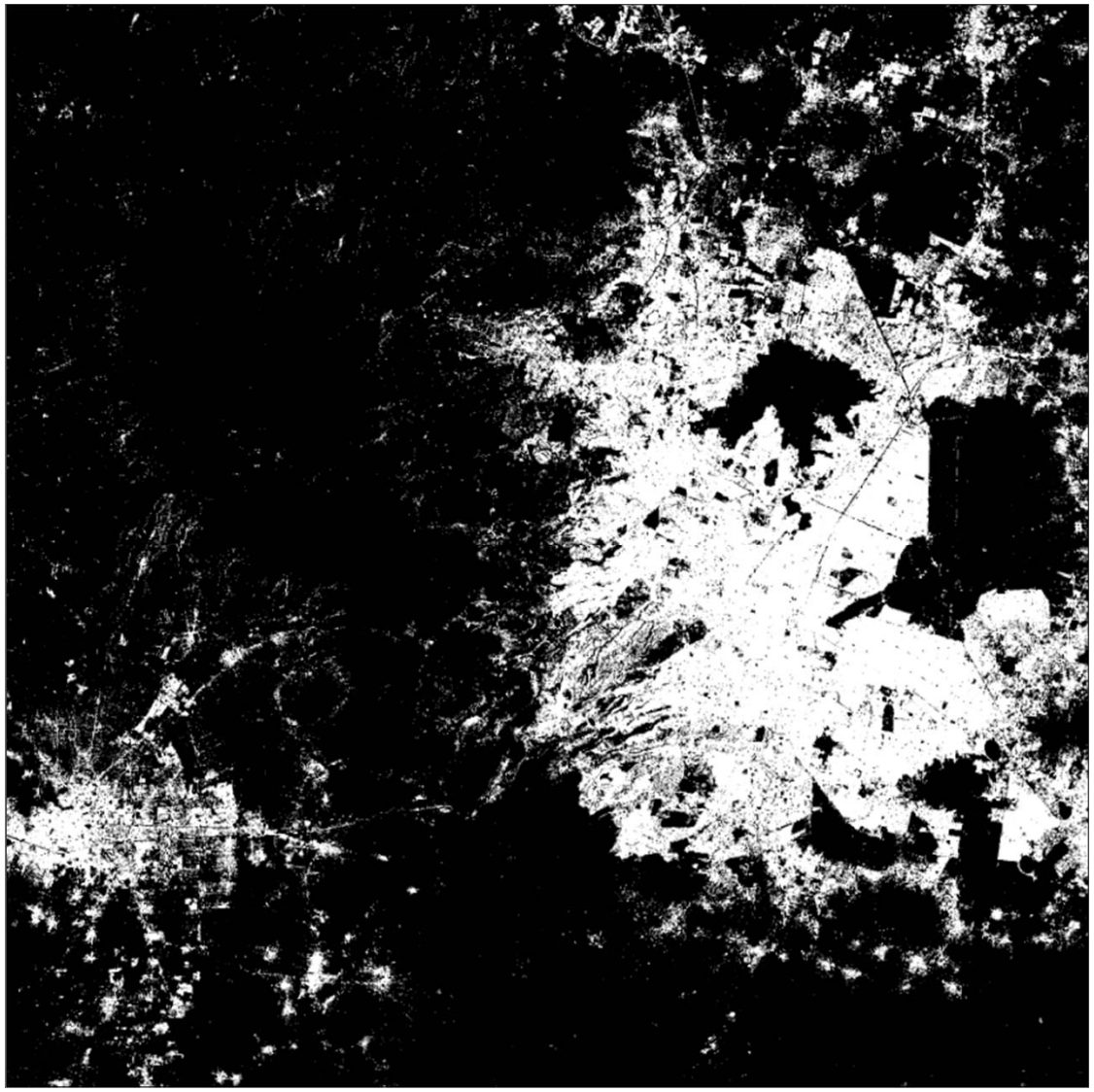


S1A IW GRDH VV
2014-2015
10m spatial resolution
30 scenes
ASCENDING PASS
Unsupervised Method

DLR

First Results

Mexico City

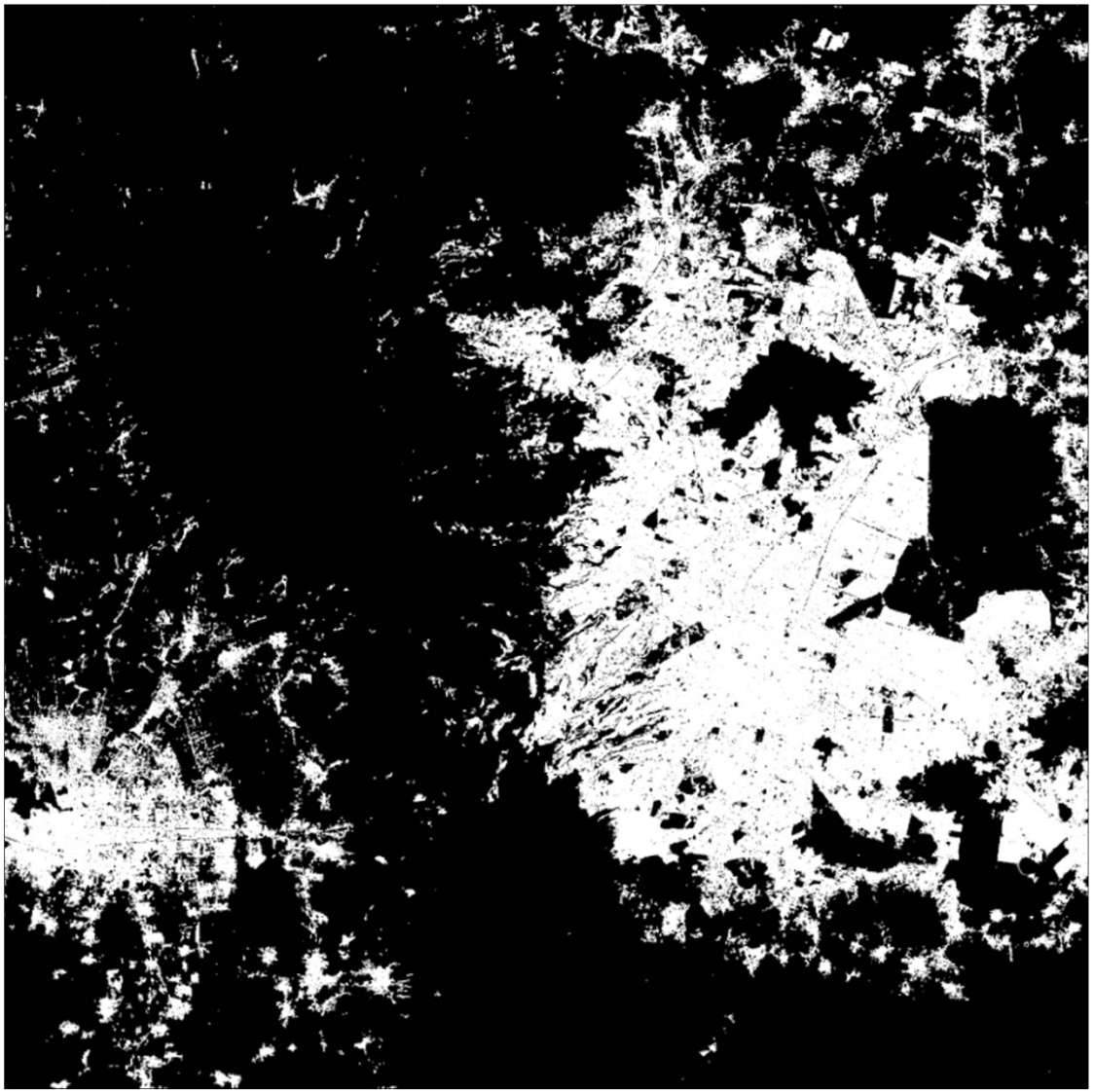


S1A IW GRDH VV
2014-2015
10m spatial resolution
combination
ASCENDING +
DESCENDING PASS
Unsupervised Method

DLR

First Results

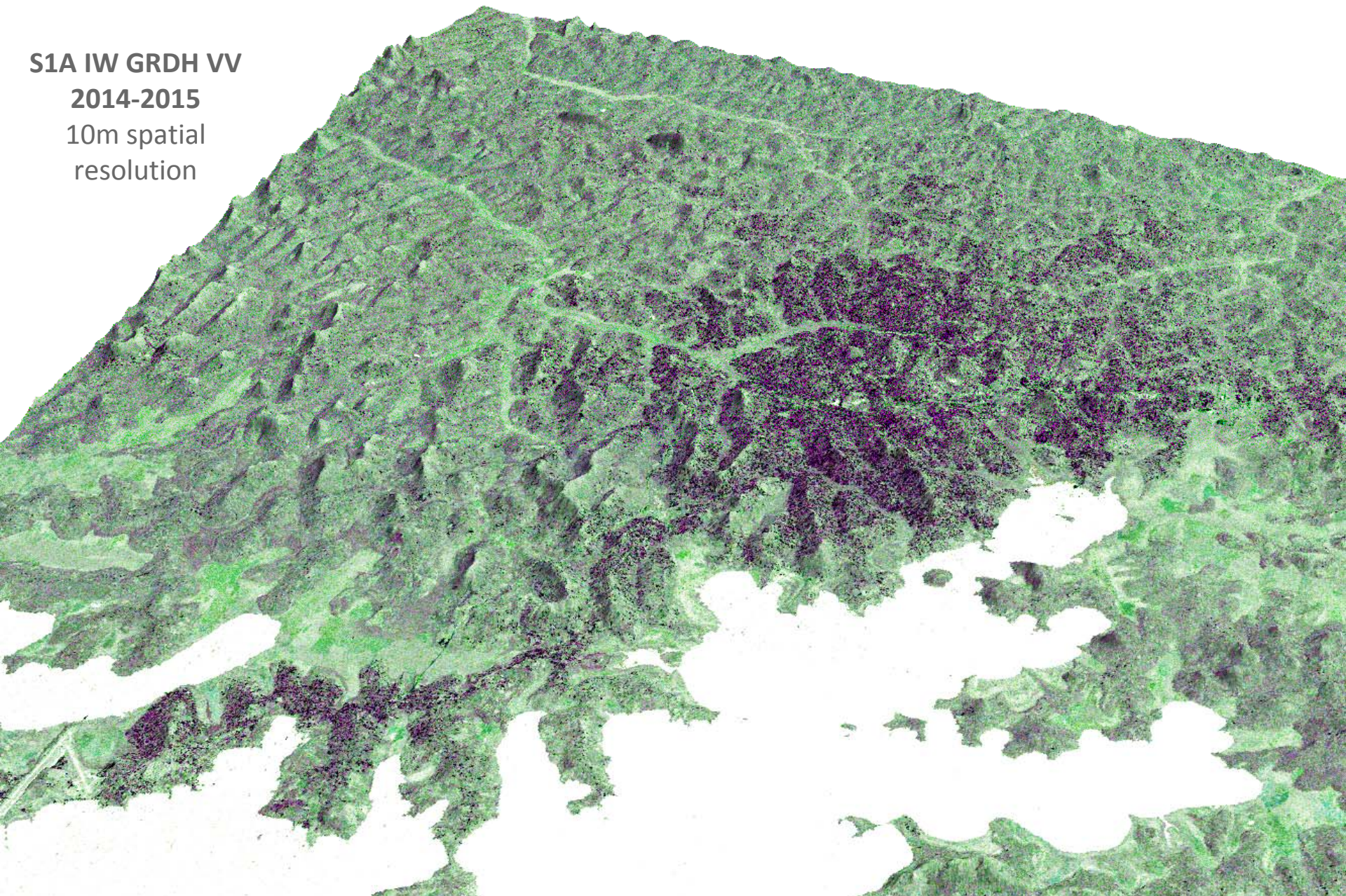
Mexico City



First Results

Kampala

S1A IW GRDH VV
2014-2015
10m spatial resolution



First Results

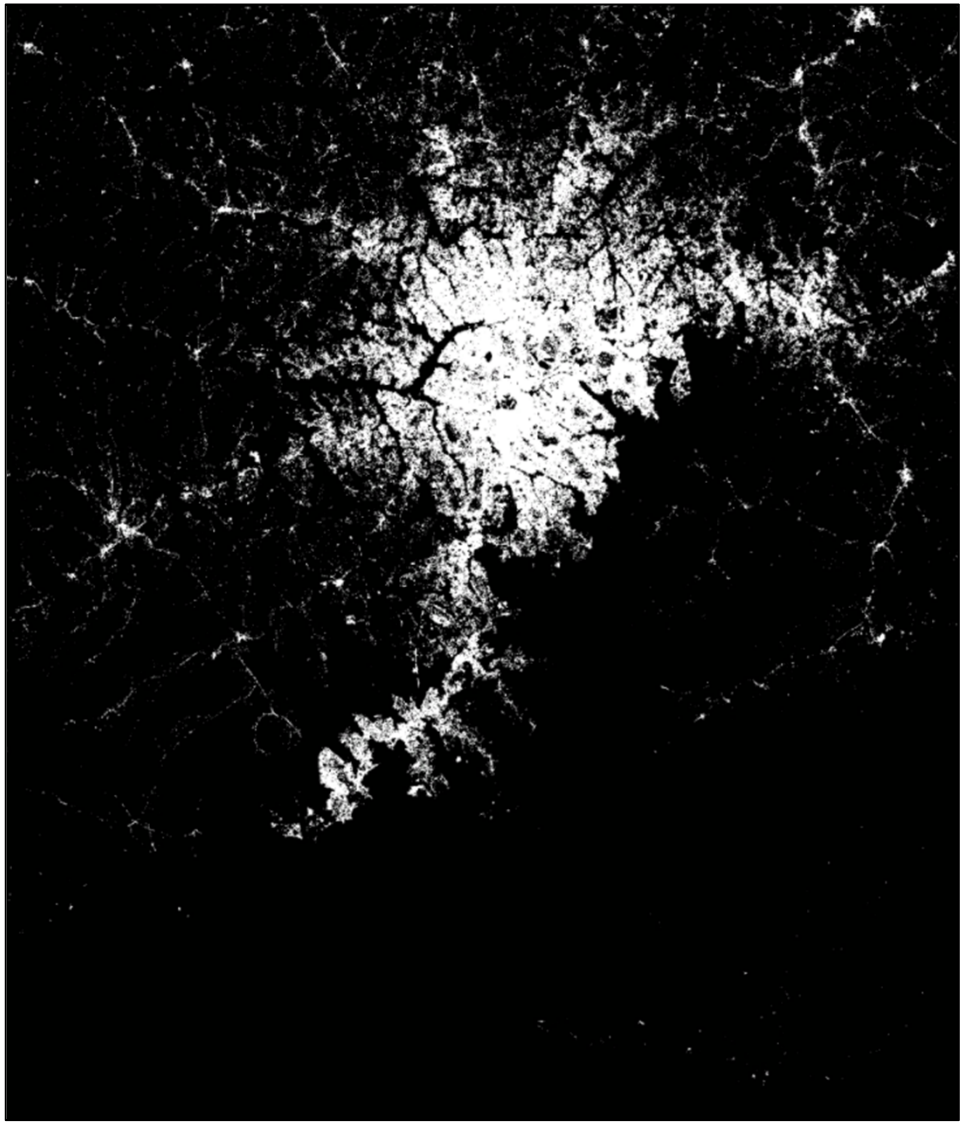
Kampala

Google Earth

DLR

First Results

Kampala

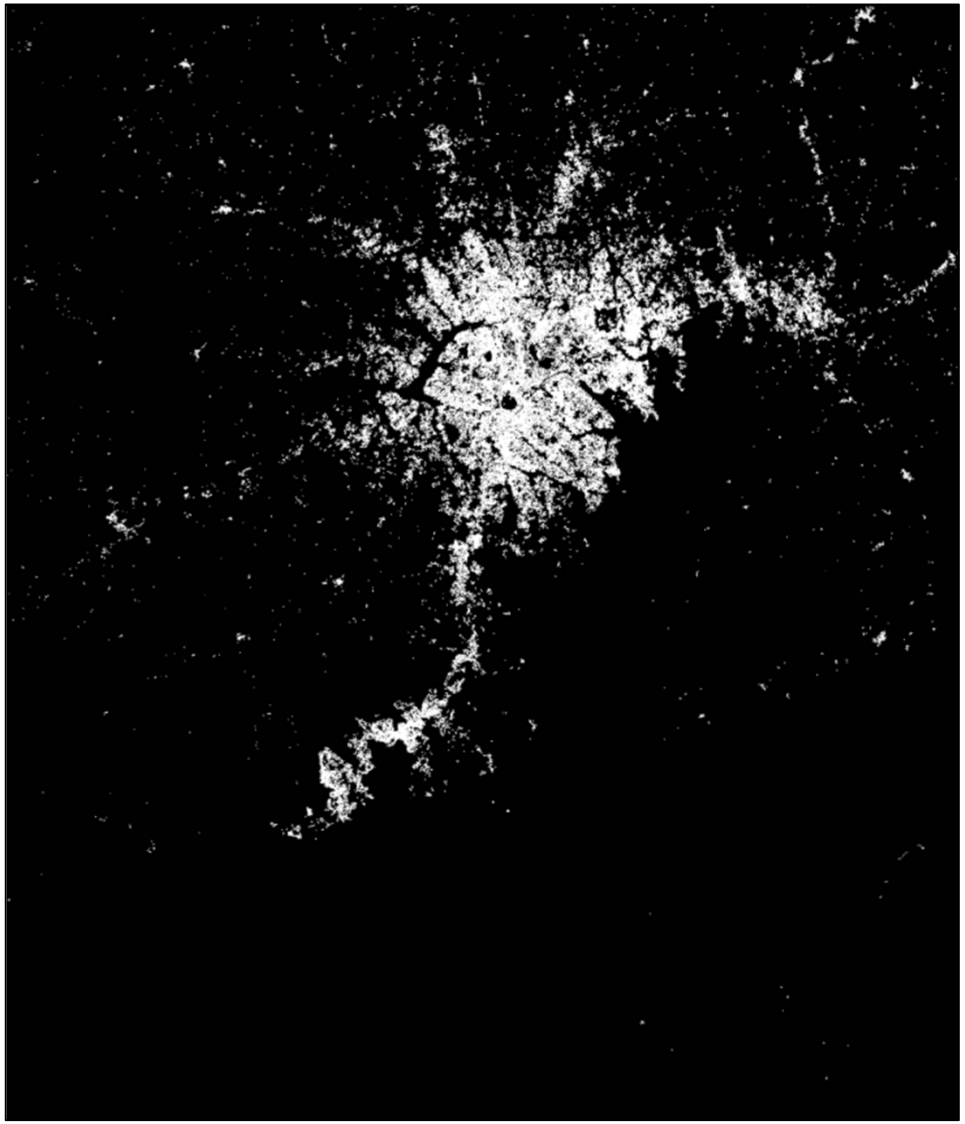


S1A IW GRDH VV
2014-2015
10m spatial resolution
combination
ASCENDING +
DESCENDING PASS
Unsupervised Method

DLR

First Results

Kampala



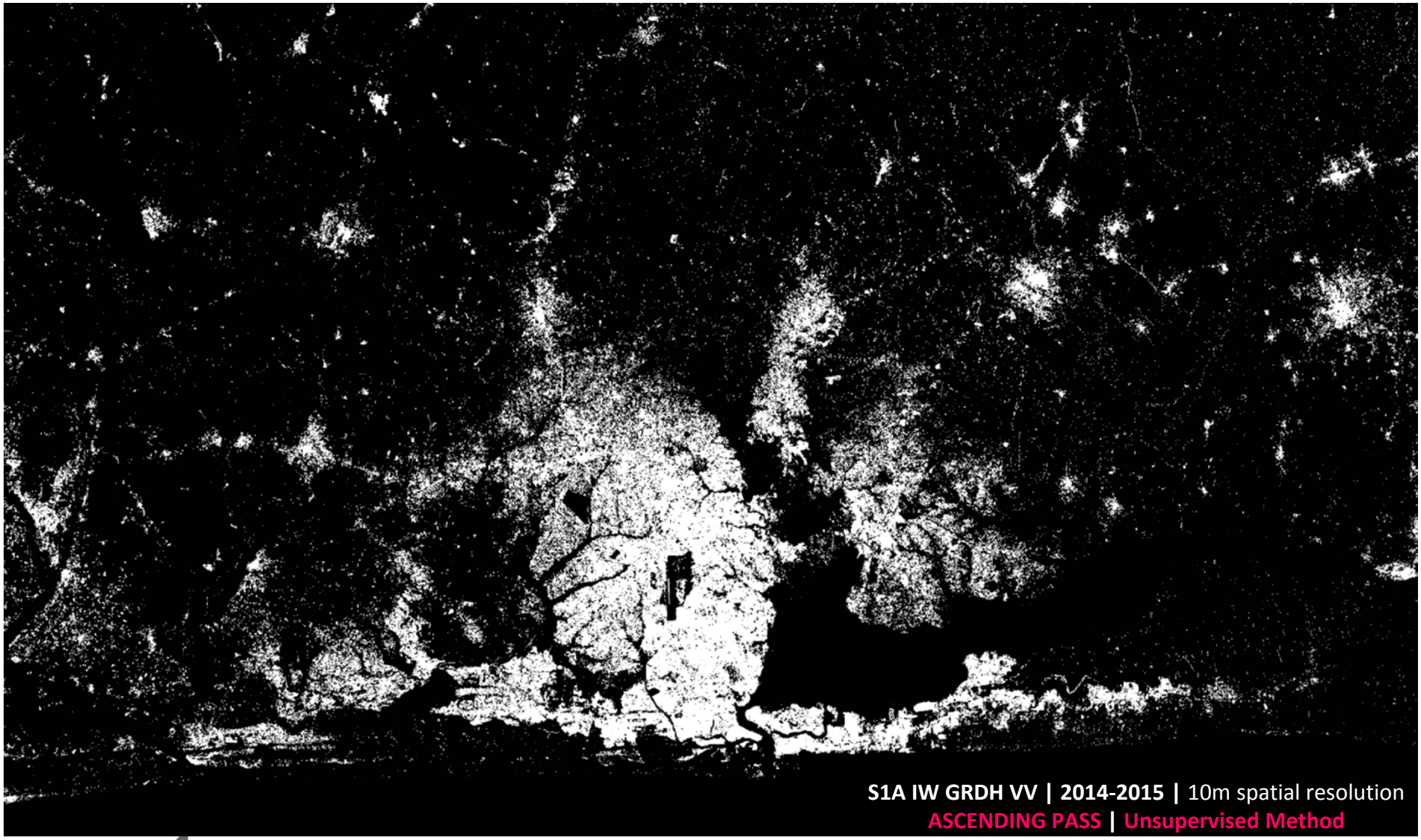
First Results

Lagos

DLR

First Results

Lagos

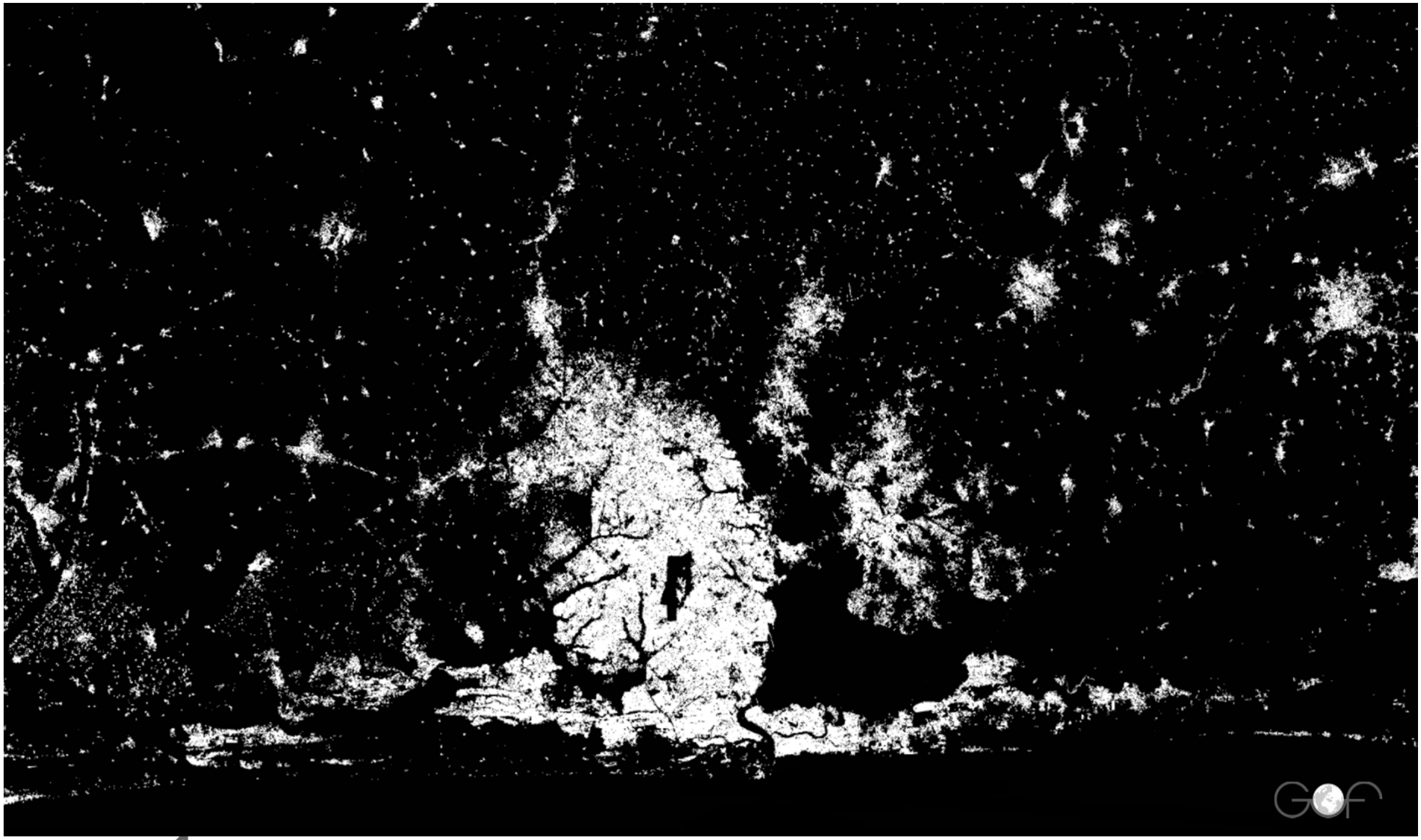


S1A IW GRDH VV | 2014-2015 | 10m spatial resolution
ASCENDING PASS | Unsupervised Method

DLR

First Results

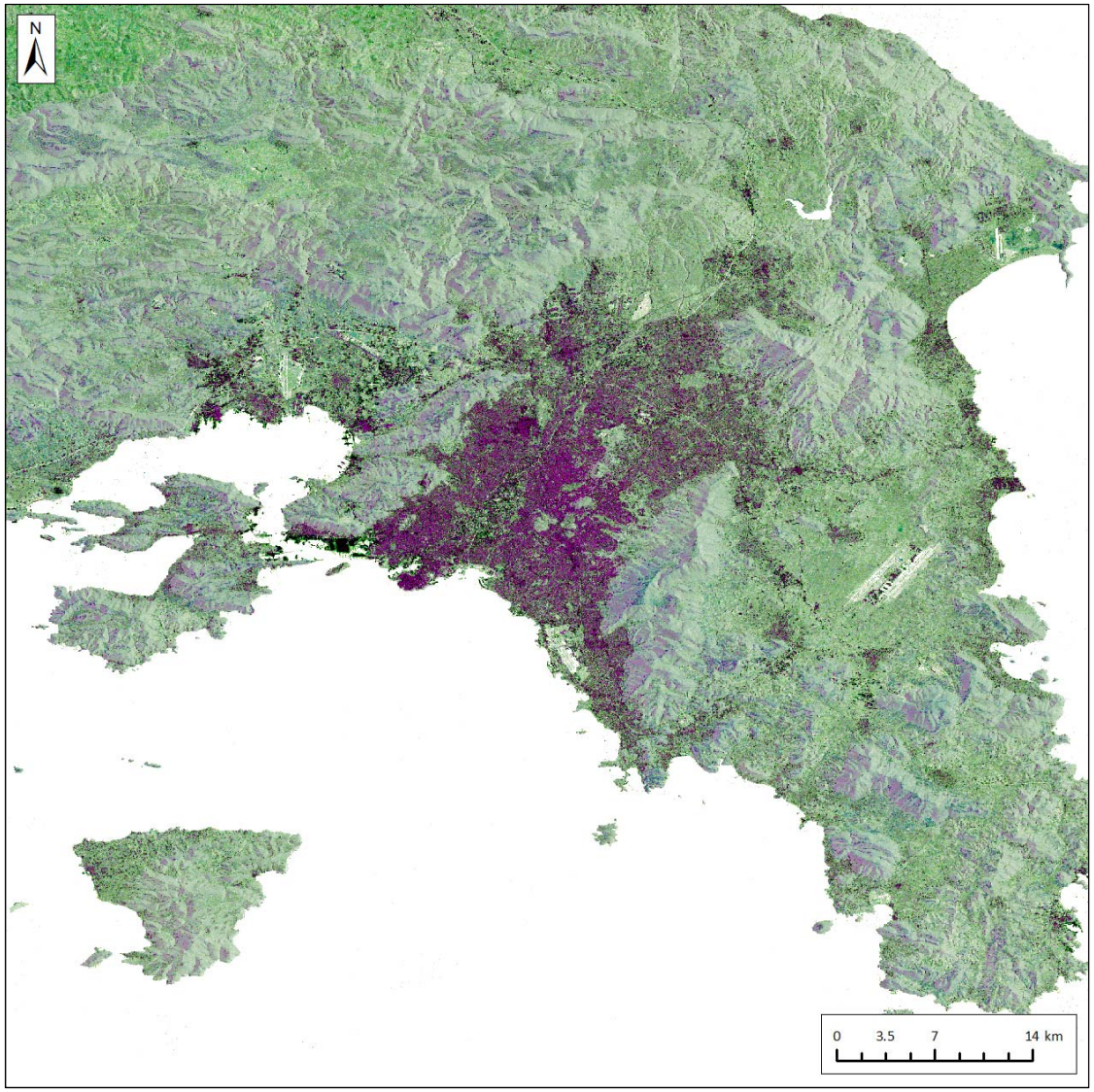
Lagos



DLR

First Results

Athens

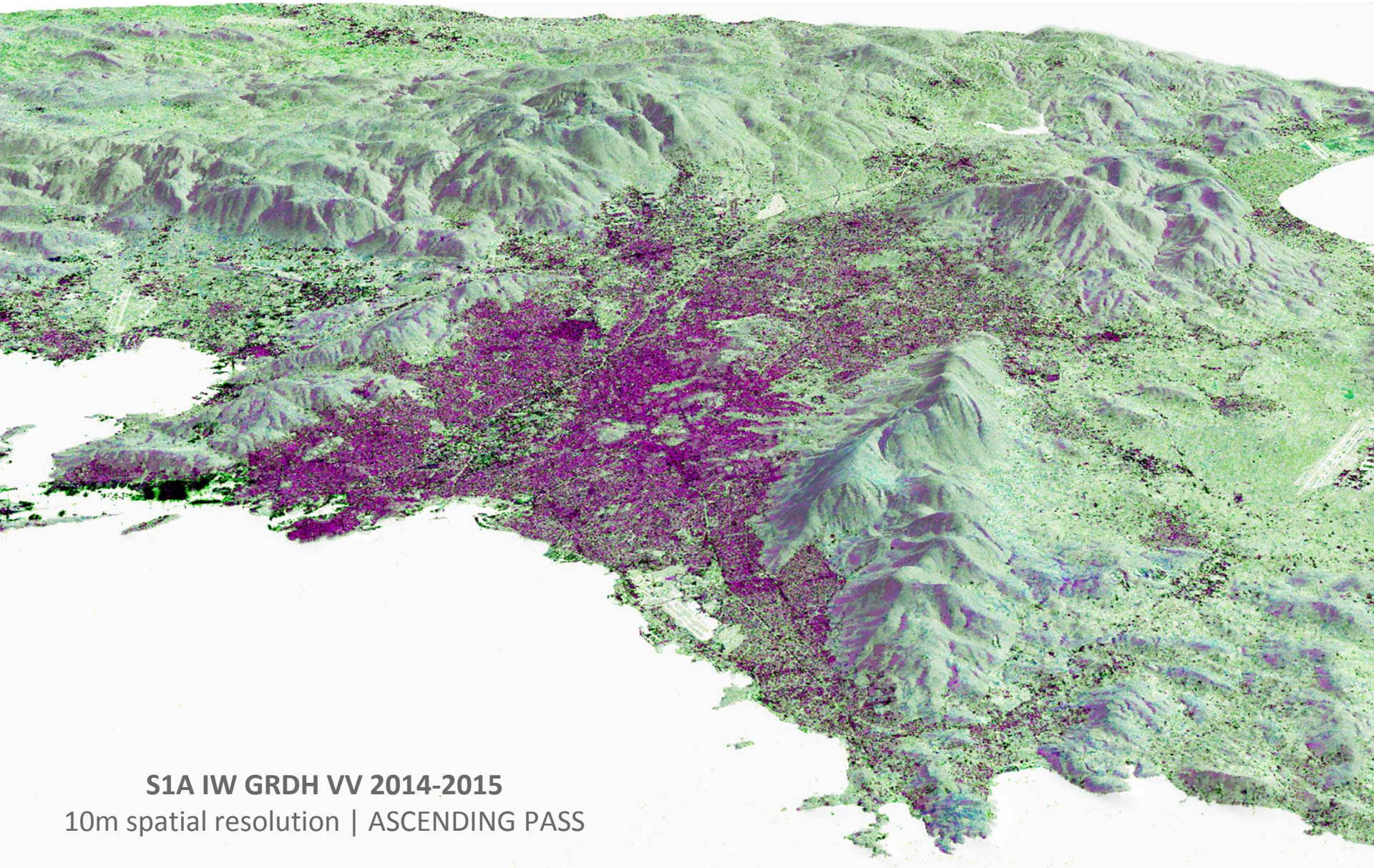


S1A IW GRDH VV
2014-2015
10m spatial resolution
48 scenes
ASCENDING PASS

DLR

First Results

Athens

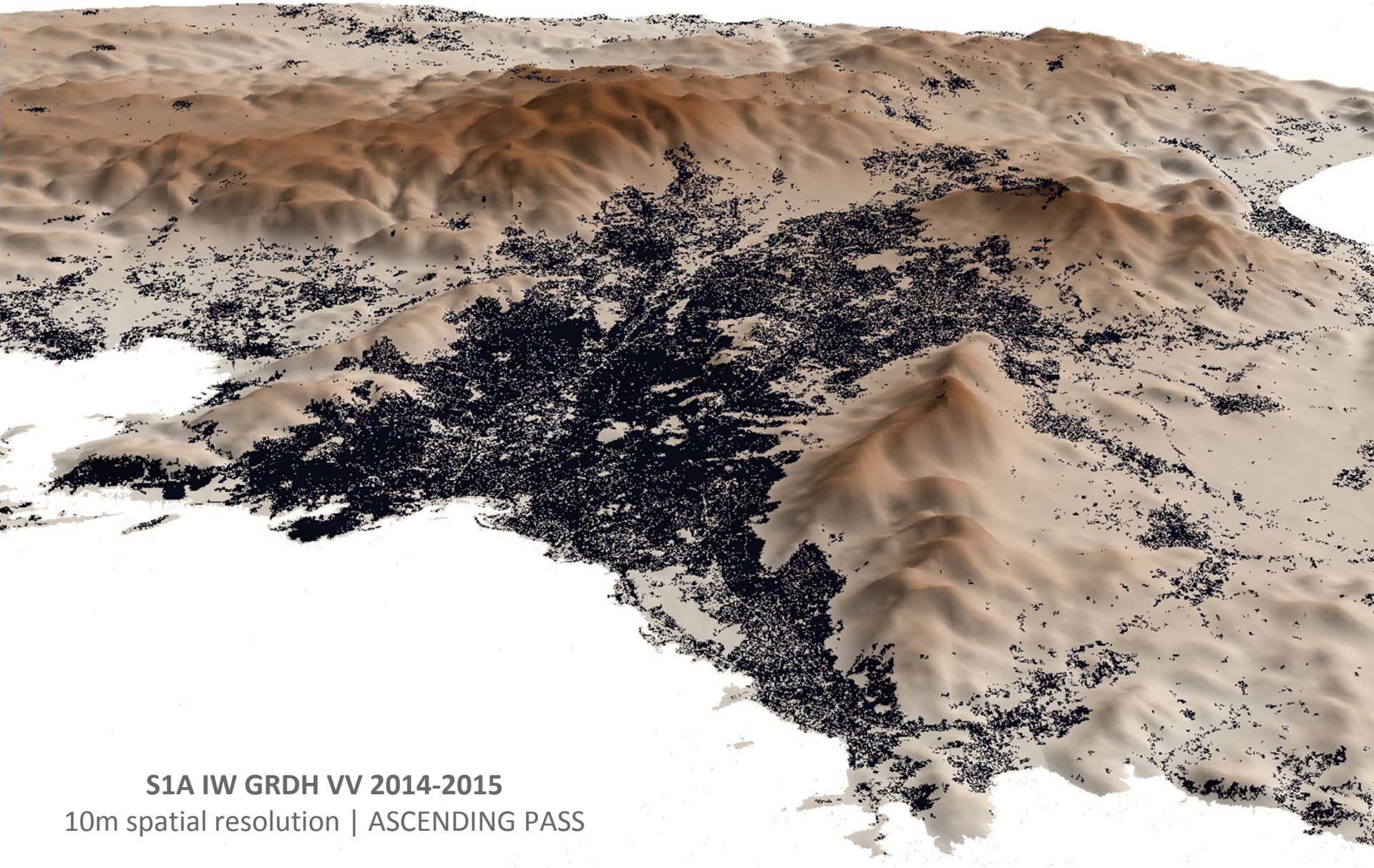


S1A IW GRDH VV 2014-2015

10m spatial resolution | ASCENDING PASS

First Results

Athens



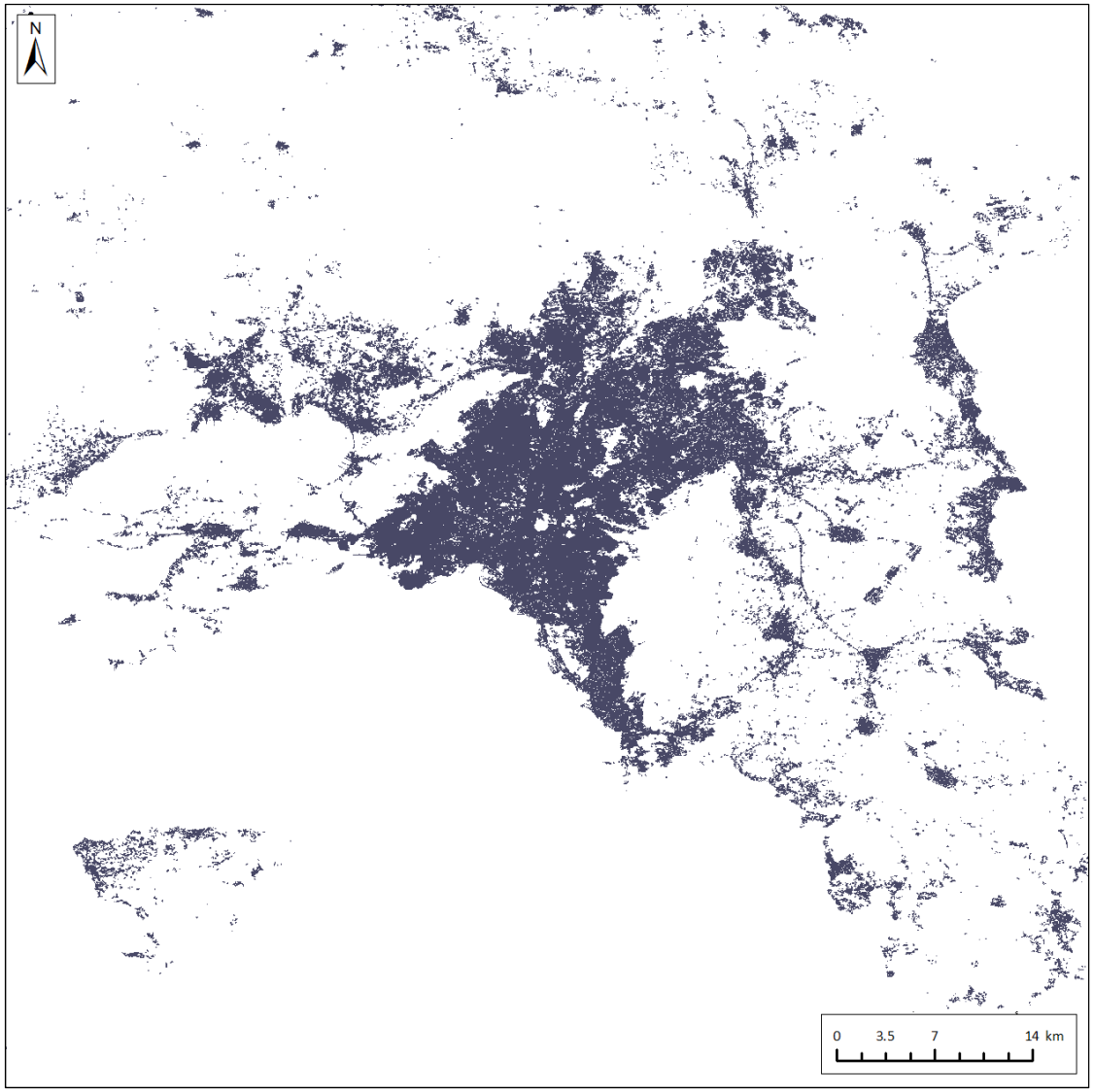
S1A IW GRDH VV 2014-2015

10m spatial resolution | ASCENDING PASS

First Results

Athens

2014-2015

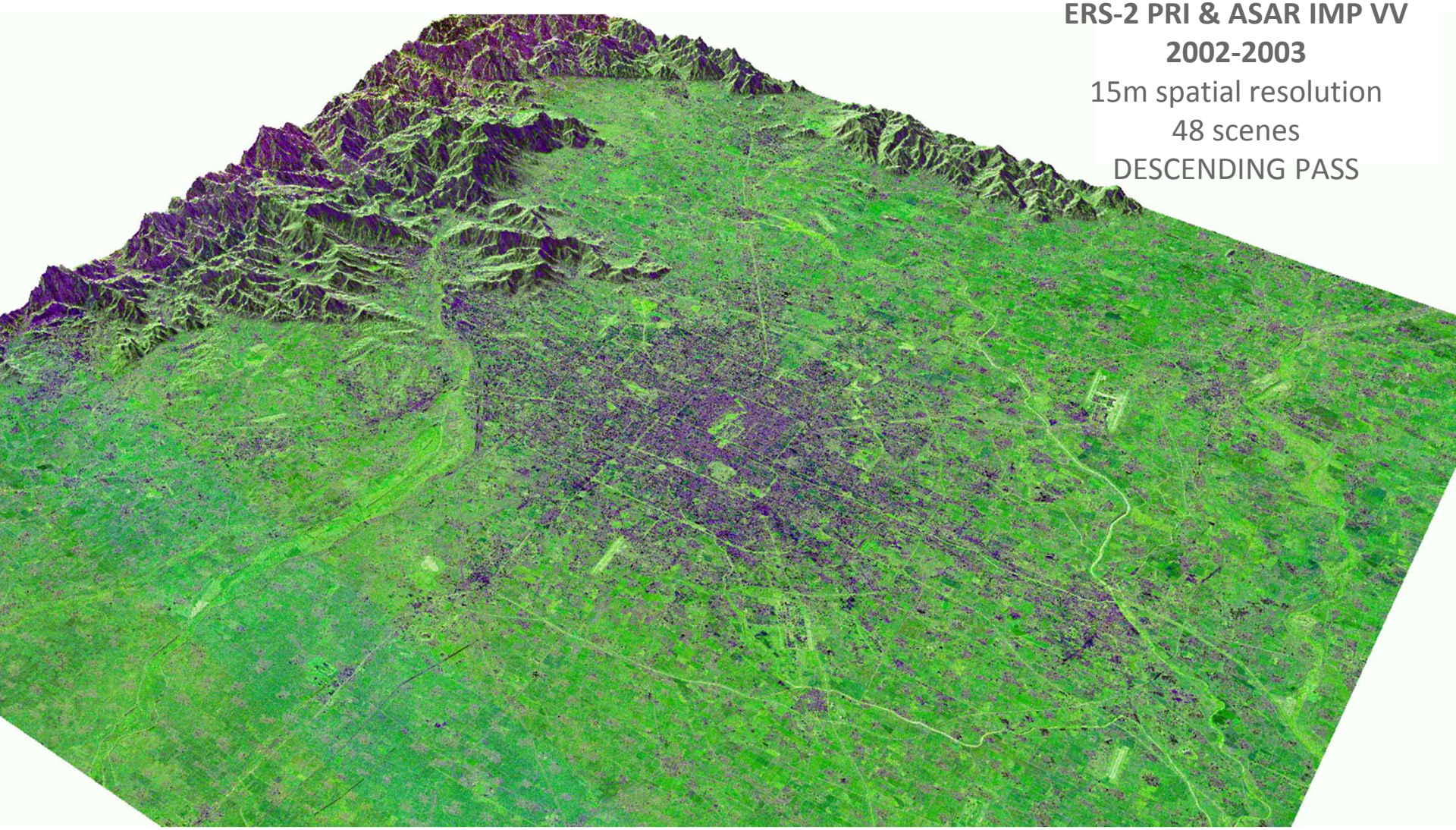


DLR

First Results

Beijing

ERS-2 PRI & ASAR IMP VV
2002-2003
15m spatial resolution
48 scenes
DESCENDING PASS

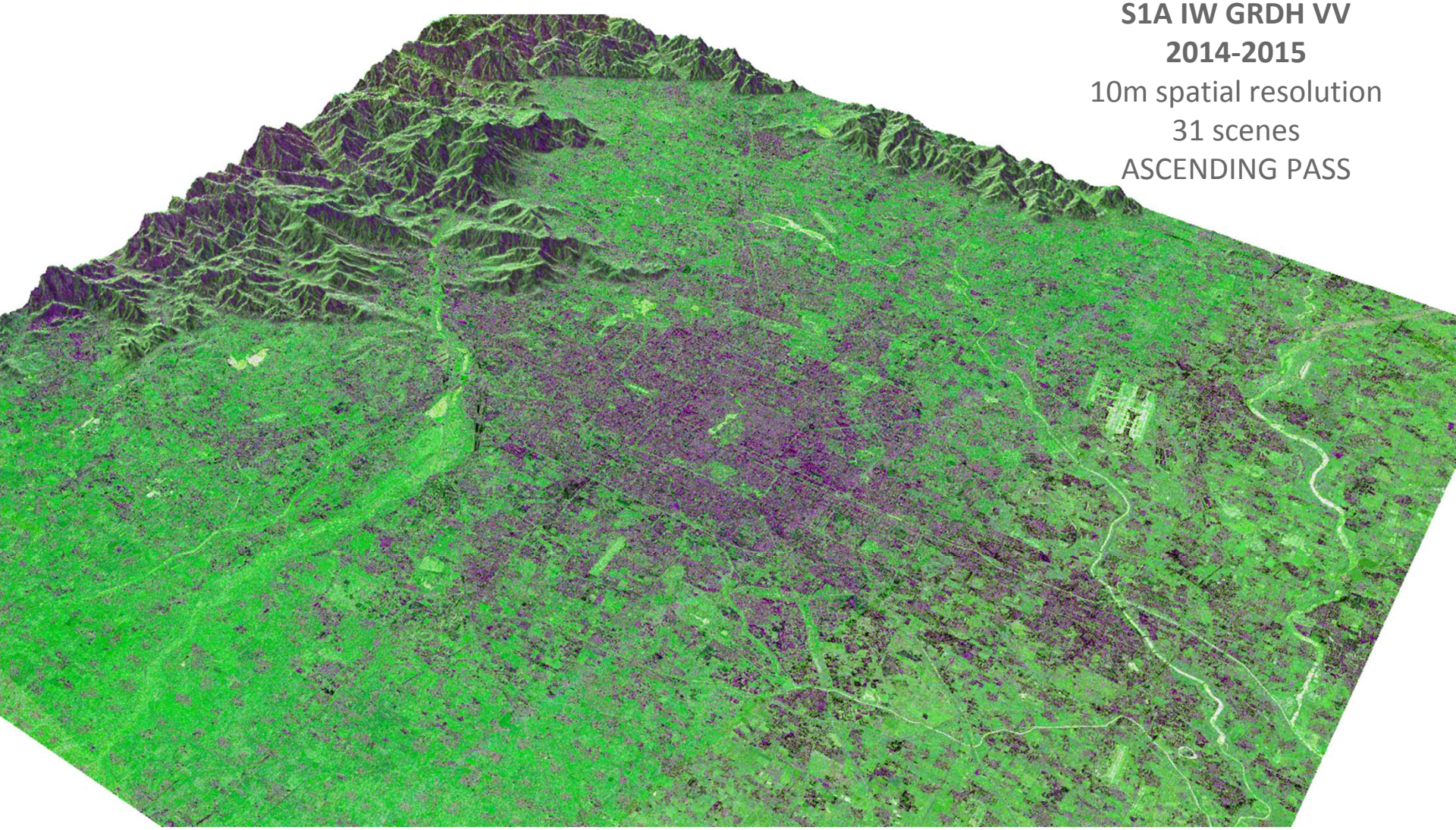


DLR

First Results

Beijing

S1A IW GRDH VV
2014-2015
10m spatial resolution
31 scenes
ASCENDING PASS



DLR

First Results

Beijing

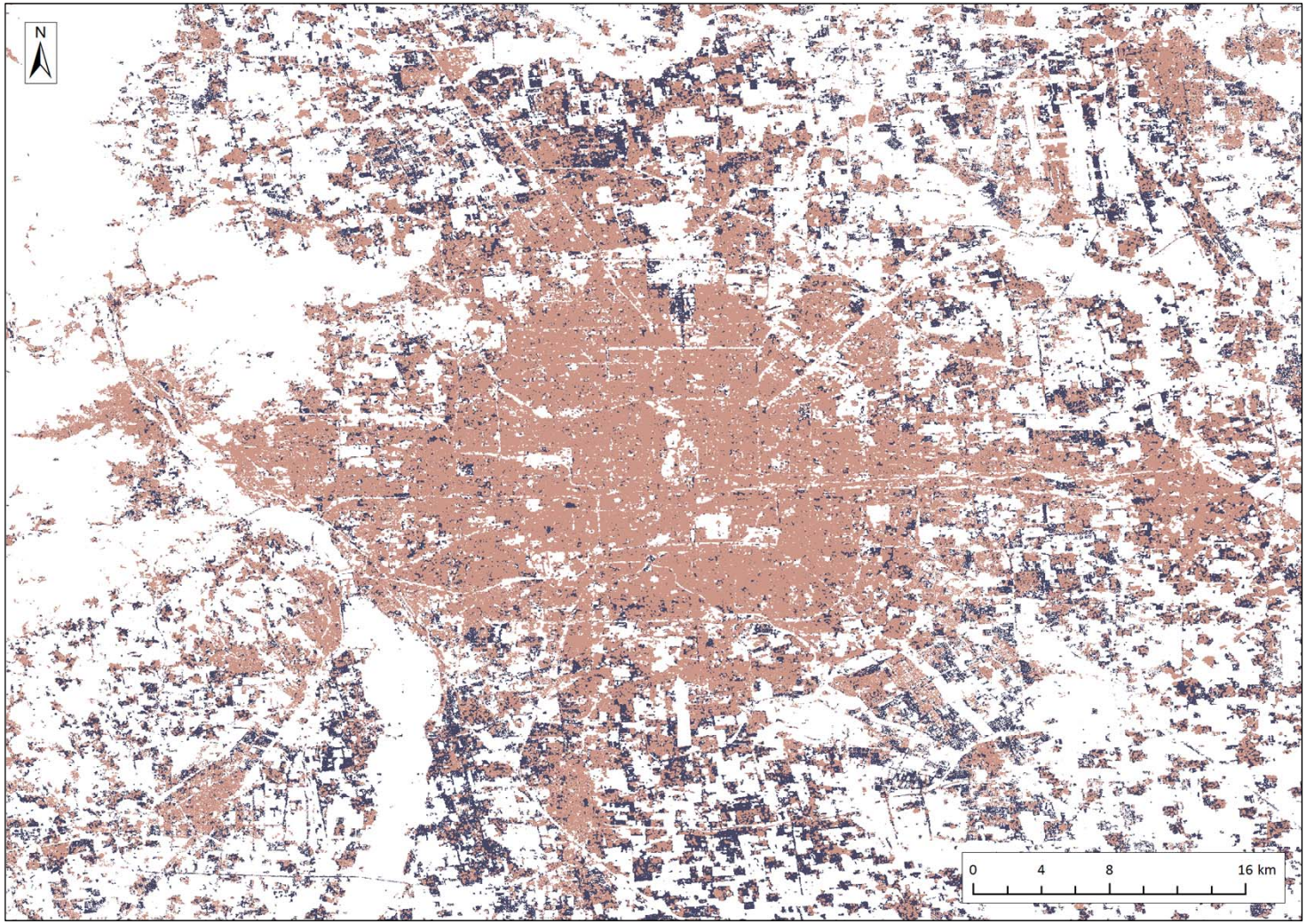
2002-2003

DLR

First Results

Beijing

2009-2012 2002-2003

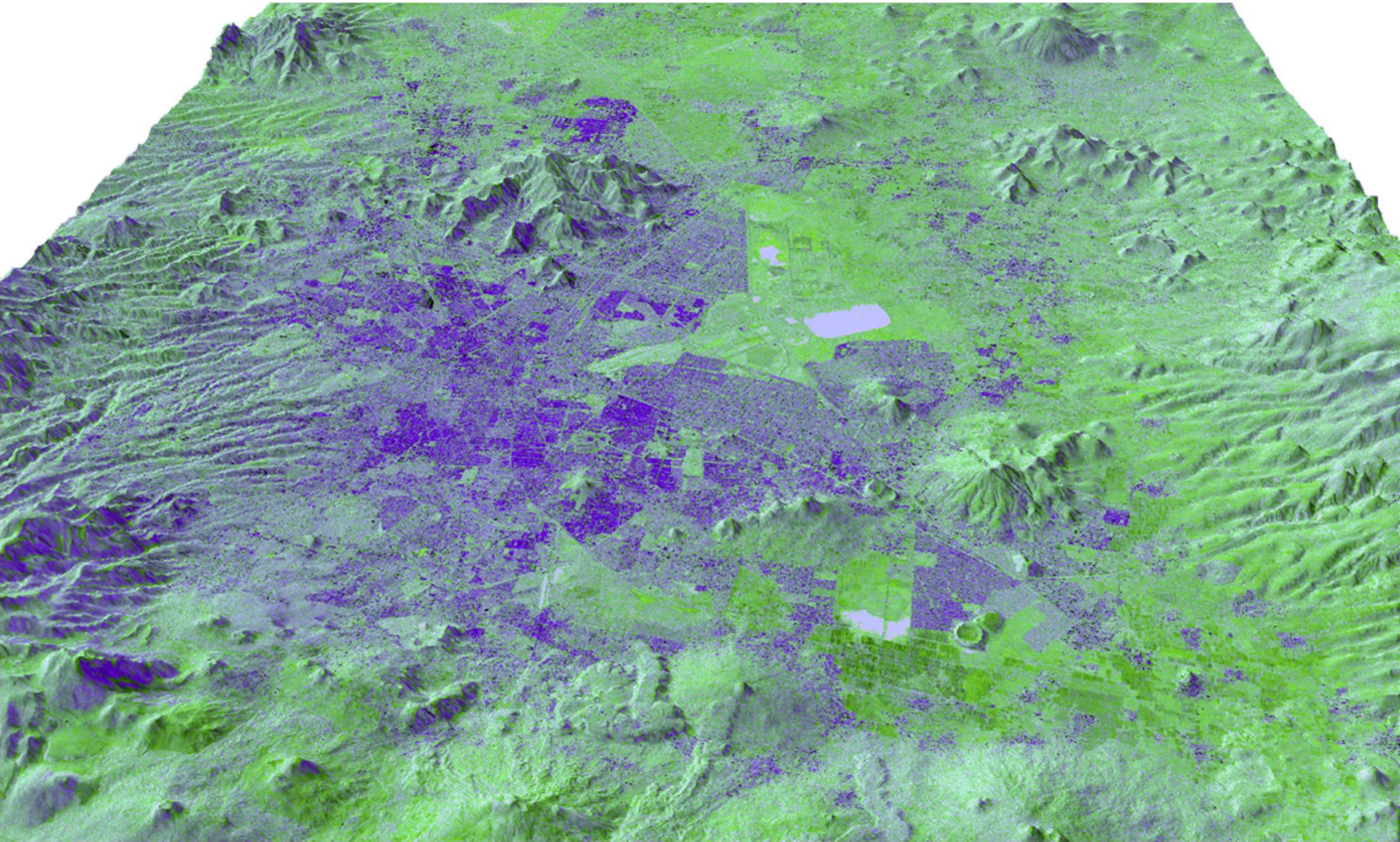


DLR

First Results

Mexico City

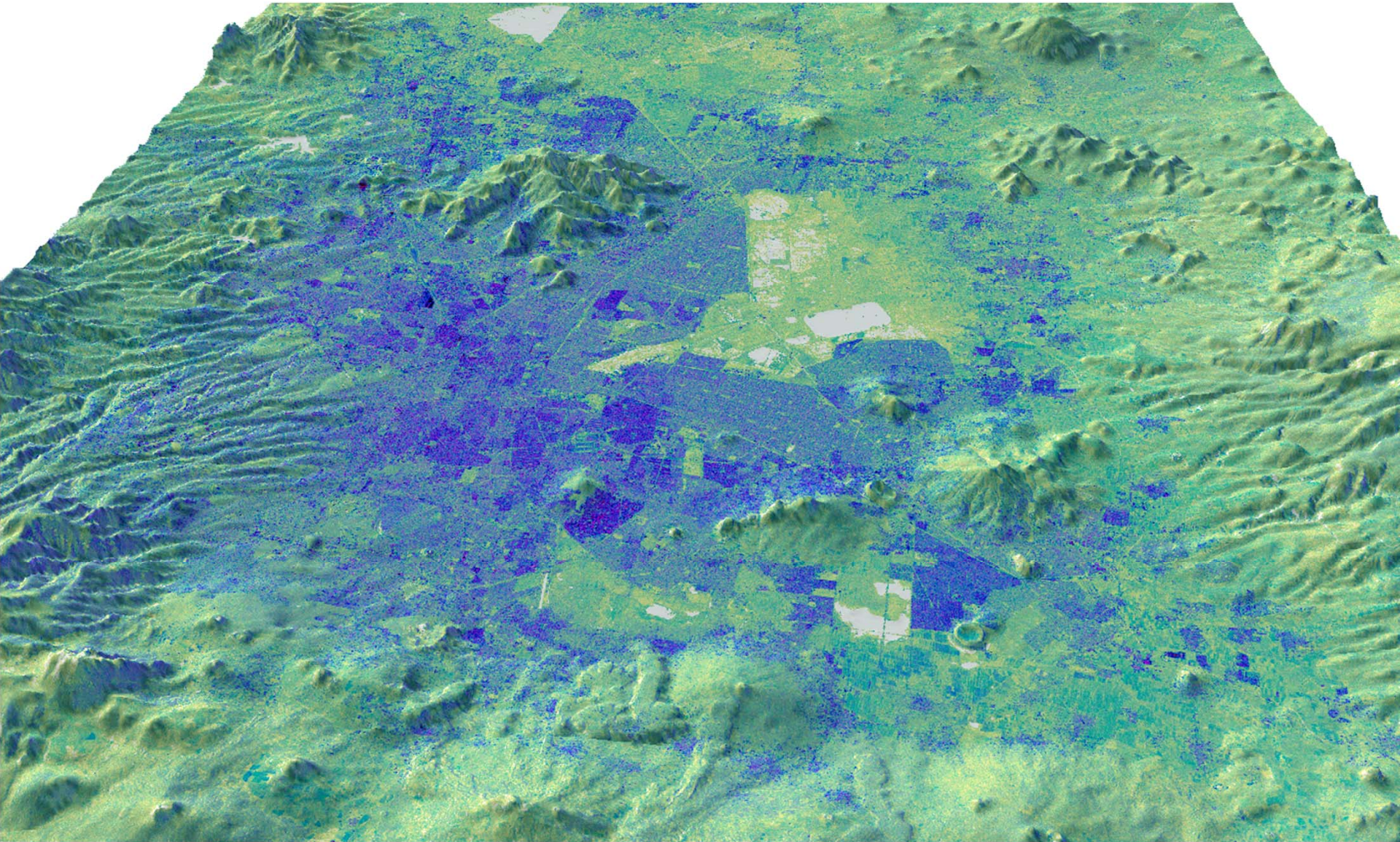
ERS-2 PRI & ASAR IMP VV 2002-2003 | 15m spatial resolution | 41 scenes



First Results

Mexico City

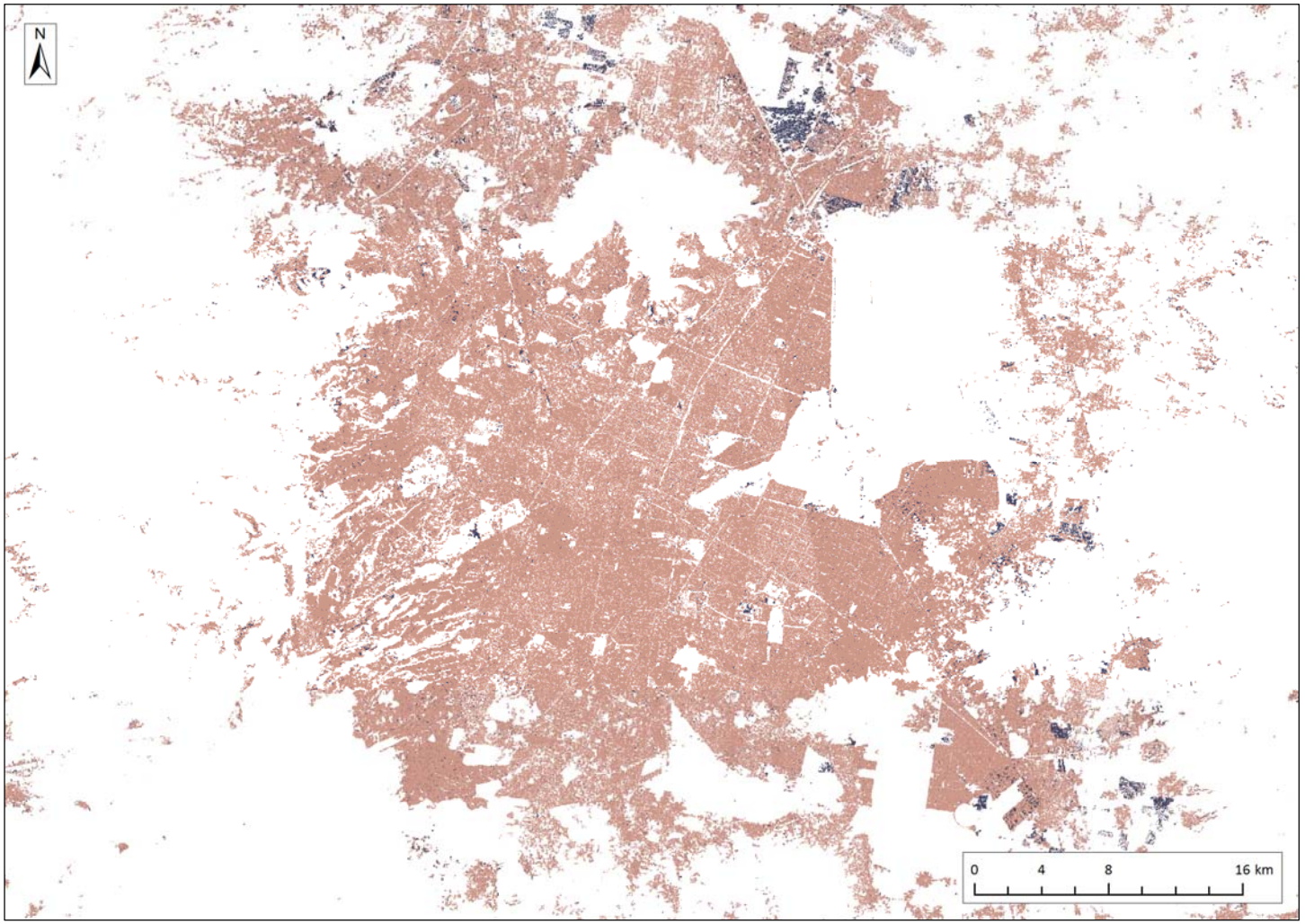
S1A IW GRDH VV | 10m spatial resolution | 49 scenes



First Results

Mexico City

2009-2012 2002-2003



DLR

Outlook

- Implemented classification system proved very promising for all considered type of data;
- Great potential for operational employment with S1 data at the global scale;
- Further experimental trials for assessing the robustness;
- **Validation** (yet ongoing):
  - validation plan;
  - interaction with local representatives for getting reference data;

thanks a lot for your attention

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Fax: +49-8153-28-1445
Email: mattia.marconcini@dlr.de